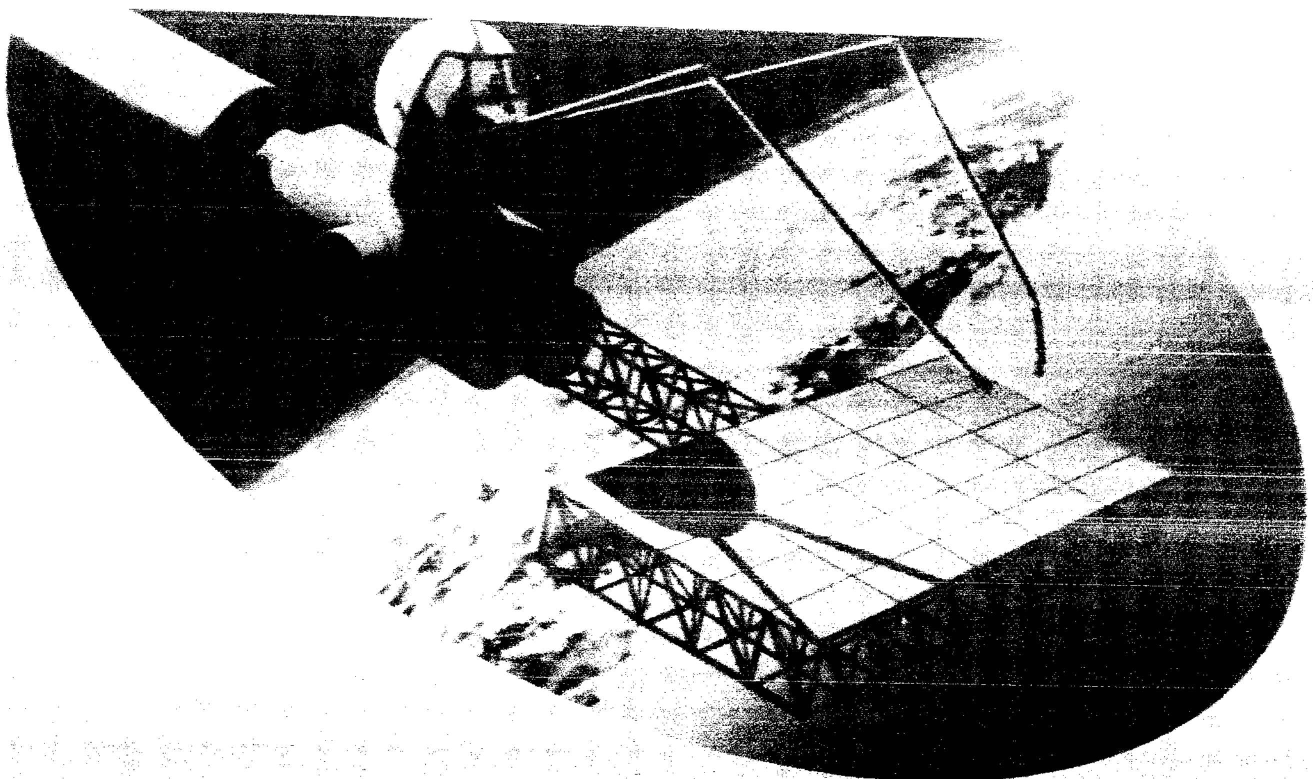
IN-SPACE RESEARCH, TECHNOLOGY AND ENGINEERING (RT&E) WORKSHOP

VOLUME 7 OF 8

AUTOMATION AND ROBOTICS



NATIONAL CONFERENCE CENTER
WILLIAMSBURG, VIRGINIA
OCTOBER 8-10, 1985

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

OAST
Office of Aeronautics
and Space Technology
Washington, DC

NOTICE

The results of the OAST Research, Technology, and Engineering Workshop which was held at the National Conference Center, Williamsburg, Virginia, October 8-10, 1985 are contained in the following reports:

VOL 1	Executive Summary
VOL 2	Space Structure (Dynamics and Control)
VOL 3	Fluid Management
VOL 4	Space Environmental Effects
VOL 5	Energy Systems and Thermal Management
VOL 6	Information Systems
VOL 7	Automation and Robotics
VOL 8	**In-Space Operations**

Copies of these reports may be obtained by contacting:

NASA Langley Research Center
Attn: 288/Dr. Roger A. Breckenridge
Hampton, VA 23665

Commercial Telephone: (804) 865-4834
Federal Telephone System: 928-4834

AUTOMATION AND ROBOTICS

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FOREWORD

Within NASA, the Office of Aeronautics and Space Technology (OAST) has the responsibility for timely development of needed new technologies. Traditionally, the development of new concepts, new materials, designs, and engineering techniques for aeronautics has been accomplished in close cooperation with the aircraft industry and with the great American universities. On the other hand, NASA, as the primary user of space flight, has been its own principal customer for new space technologies.

A new era of permanent presence in space is beginning with the Space Station. This permanent presence will permit and promote commercial ventures and privately funded research in the tradition of university/industry cooperation.

The RT&E workshop in Williamsburg represents a significant milestone for NASA and the space engineering community. It marked the initiation of a long-term program of outreach by NASA to focus the needs of universities, industry, and government for in-space experiments and to begin building a strong national user constituency for space research and engineering.

These proceedings represent a "first-cut" planning activity to involve universities, industry, and other government agencies with NASA to establish structure and content for a national in-space RT&E program. More interactions are needed - more workshops will follow. Program adjustments will be made. A truly national program will evolve, and its beginnings are presented here with the hope and determination needed to make it a program we can all take pride in.

- Raymond Colladay

INTRODUCTION

Among the purposes of the Research, Engineering, and Technology Workshop, an interest in validating the RT&E theme concept has some direct effect on the form of these proceedings. The original five themes, which were themselves a target for validation or recommeded changes, have become seven. During preparations for the workshop, the submitted papers and attendance plans made it evident that the fifth "theme", In-space Operations, was too broad, and would need to be split. As the workshop got underway, a further split occurred, brought about by the different levels of maturity, and needs for technology planning in several sub-disciplines. Thus, these proceedings are presented under seven themes. The volume of presentations, and the quantity of information generated by the individual panel summaries has led to the decision to prepare the proceedings in several volumes.

The first volume is an executive summary and includes the summary presentations made by the panel co-chairmen in the final plenary session. The accompanying seven volumes, of which this is one, each represent a specific "theme", and include the un-edited original presentation material used in that particular panel workshop. Each of these separate "theme" volumes also include the Foreword, the general Summary and Conclusions, and the Chairman's presentation charts and narrative summary. Thus, each should represent a self-standing volume to reflect the proceedings relevant to its respective Panel deliberations and output, as well as the reflection in the general Workshop results.

WORKSHOP THEME

Automation and Robotics

--Mobility

--Dextrous Manipulation

--Supervised/Autonomous Robots

--Advanced Concepts

SUMMARY AND CONCLUSIONS

NASA's In-Space Research, Technology, and Engineering (RT&E) Workshop brought together representatives of the university community, private sector, and government agencies to discuss future needs for in-space experiments in support of space technology development and the derivative requirements for space station facilities to support in-space RT&E.

The workshop provided an excellent forum for establishing an interactive process for building a national in-space experiments program. It enabled NASA to present to the user community (university and private sector) experiment concepts for NASA's technology development activities in support of future space missions. The meetings also began a process by which industry and university researchers will be able to bring their own TDM requirements to NASA's planning process.

This conference reached three primary goals: first, it expanded and validated NASA's in-space experiment theme areas, including Space Structure (Dynamics and Control), Space Environmental Effects, Fluids Management, Energy Systems and Thermal Management, Automation and Robotics, Information Systems and In-Space Operations; second, it began the development of a user community network which will interface with NASA throughout the lifetime of the in-space experiment program; and third, it formed the basis for the establishment of on-going working groups which will continue to interest and coordinate requirements for in-space RT&E activities.

As an adjunct to the conference, NASA/OAST announced plans to initiate a long-term program to encourage and support industry and university experiments. NASA's modest investment in this program is initially targeted for generating experiment ideas and concepts. It is anticipated that this base of concepts will lead to cooperatively funded experiments between NASA, industry, and academia and thereby, begin to build an active in-space RT&E program.

Several key points emerged from this conference regarding the adequacy of the TDM data base that should be addressed in future planning activities. First, many of the experiments could be performed on the ground, i.e., they do not justify a space experiment. Secondly, many of the experiments address near-term or current applications and do not take into account advanced system requirements. The TDM data base must look beyond extensions of current programs to reflect future needs and trends to have an effective and useful impact on space station planning and design. This will require increased input from industry and university researchers and engineers.

In order to address these concerns, it is imperative that a long-range planning view be taken in which industry and university researchers help NASA derive the technology development program. The following recommendations have been developed on the basis of the workshop:

1. Development of an on-going RT&E university and industry advisory group;
2. Continuation of in-space RT&E symposia to act both as outreach mechanisms and as working sessions to refine the TDM data base;
3. Development of an RT&E information clearinghouse;
4. Development and continuation of the new experiments outreach activity announced at the RT&E workshop;
5. Development of an "impacts assessment group" which will focus its energy on identifying experiment accommodation requirements to impact the design of in-space facilities, i.e., space station and others.

If carried out, these recommendations constitute movement toward development of an effective NASA/industry/university partnership in a National In-Space RT&E Program. This will also enable NASA/OAST to have an effective voice in space station planning, which is essential toward the success of a future in-space activities. The workshop, by promoting the process of NASA/industry/university interactions and by pointing out concerns with the developing TDM data base has provided an important first step towards a successful long-term space technology development effort.

IN-SPACE RESEARCH, TECHNOLOGY, AND ENGINEERING WORKSHOP

AUTOMATION AND ROBOTICS

LEE HOLCOMB	OAST	CO-CHAIRMAN
ROGER SCHAPPELL	MMC	CO-CHAIRMAN
ED BERGMANN	CSDL	EXEC. SECRETARY
DAVE AKIN	MIT	MEMBER
RAY HALLETT	GE	MEMBER
JERRY WALD	HONEYWELL	MEMBER
RICK RINEY	MMA	MEMBER
JOHN MANKINS	JPL	MEMBER

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98

AUTOMATION AND ROBOTICS SUMMARY
Lee Holcomb

The Automation and Robotics panel recommended an evolutionary set of in-space robotic capabilities be developed starting with rendezvous and docking (1988), simple satellite servicing (1990), structural assembly (1992), and robotic assistants for IVA (1996), and EVA (2000) operations. During this time frame the nature of robotic capability will evolve from telepresense to supervisory control and ultimately to autonomous operations. The panel felt that in-space related experiments were essential; however, they felt most AI-based systems autonomy capabilities could be demonstrated on the ground.

In-space robotic experiments are needed to evaluate our analytical predictions of zero-G dynamics of mechanical equipment. The result of in-space experimentation would be a design/operational database on telerobotic capability. Experimentation would provided evaluation of the man/machine performance on-orbit and validation of protoflight hardware/software.

A series of experiments were proposed dealing with mobility, dextrous manipulation, supervised/autonomous operation, and evaluation of the man/machine interface. A potential list of experiments was recommended. The attached briefing package lists the experiments proposed and the critical technologies to be evaluated.

A number of accommodation issues were raised. The first and most pressing is the development of "robot friendly" interface for servicing, assembly, and docking. In addition, a "standard" set of utilities need to be defined for interface to mobility systems (RMS, MRMS, OMV, OTV, etc.). A key accommodation issues are the safety constraints for in-space robotic experiments will press beyond current plans for onboard computing and data storage capabilities.

AUTOMATION AND ROBOTICS

OBJECTIVES/CAPABILITIES

- VALIDATE ROBOTIC IN-SPACE OPERATIONS CAPABILITY
  - DOCKING - 1988
  - SATELLITE SERVICING - 1990
  - STRUCTURAL ASSEMBLY - 1992
  - IVA ASSISTANT - 1996
  - EVA ASSISTANT - 2000
- EVOLVE ROBOTIC IN-SPACE OPERATIONS CAPABILITY
  - TELEPRESENCE - 1990
  - SUPERVISORY CONTROL - 1994
  - AUTONOMOUS OPERATIONS - 1998
- SYSTEM AUTONOMY CAN BE DEMONSTRATED ON GROUND

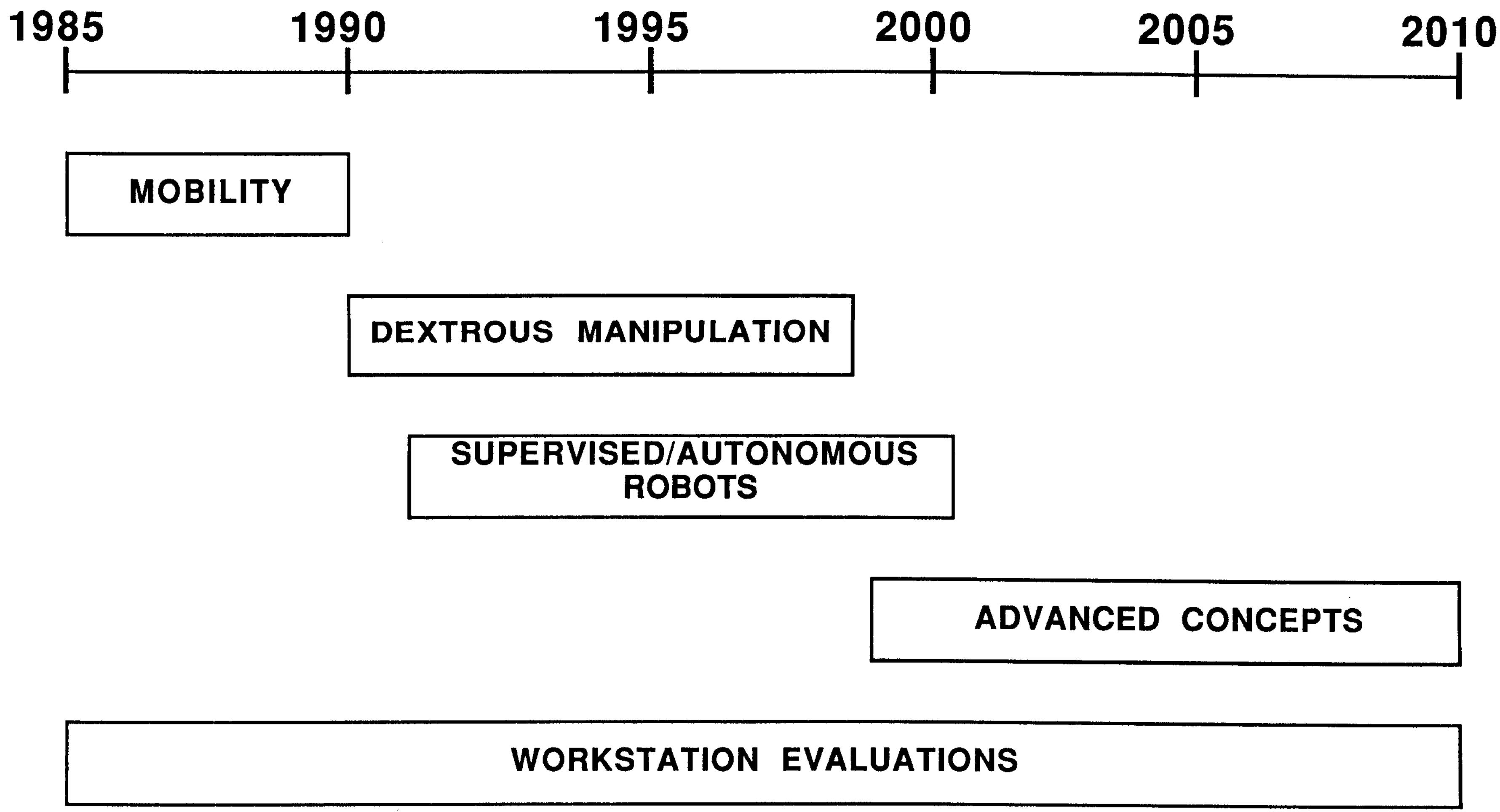
AUTOMATION AND ROBOTICS

WHY IN-SPACE EXPERIMENTS

- o EVALUATE ZERO "G" VS. ONE "G" DYNAMICS FOR:
  - MECHANICAL CONFIGURATIONS
  - PROXIMITY OPERATIONS
  - FLUIDS, SOLIDS, GASES
- o DEVELOP DESIGN/OPERATIONAL DATA BASE
- o VALIDATE PROTO FLIGHT HARDWARE/SOFTWARE/ PROCESSES
- o EVALUATE MAN/MACHINE PERFORMANCE ON-ORBIT
- o EVALUATE GROUND MODELS/SIMULATIONS
- o EVALUATE LONG TERM SPACE EFFECTS ON SYSTEMS

AUTOMATION AND ROBOTICS

EXPERIMENT THRUSTS



AUTOMATION AND ROBOTICS

EXPERIMENT LIST

1988	PROXIMITY MANEUVERING
1989	TELEOPERATED MANEUVERING (MMU)
1990	SMART FRONT AND TECHNOLOGY
1992	SATELLITE SERVICING
1994/6	SUPERVISORY STRUCTURAL ASSEMBLY
1996	IVA ROBOT
2000	AUTONOMOUS SPACE ROBOT
2010	SPACE SPIDER

CONTINUOUS WORKSTATION EVALUATION AND IN-SPACE WORKLOAD MEASUREMENTS

PRE-IOC	IOC (92-97)	FOC (97-BEYOND)
• SINGLE ARM TELEOPERATOR	• DUAL ARM TELEOPERATOR COORDINATION	• MULTI-ARM COORDINATION
• TELEOPERATION FROM EARTH • COMBINED TRANSLATION/ MANIPULATION	• TELEPRESENCE	• AUTONOMOUS ROBOTICS • MULTIPLE ROBOT COORDINATION
• FIXED ON-STATION RMS • DOCKING	• MOBILE ON STATION RMS • TELEOPERATED FREE-FLYING OPERATIONS	• FREE-FLYING AUTONOMOUS PROXIMITY OPERATIONS
	• FREE-FLYER AND DUAL-ARM COLLISION AVOIDANCE	• MULTIPLE ARM COLLISION AVOIDANCE
	• CAD-DRIVEN POSITION REGISTRATION (ON S/S)	
• END-EFFECTOR DEFINITION	• (EVOLVING)	• (EVOLVING)
• MECHANICAL ASSEMBLY PROCESS	• JOINTING	• WELDING
• WORK STATION HW/SW/MM INTERFACES	• (EVOLVING)	• (EVOLVING)
• SENSOR ACCOMMODATIONS	• (EVOLVING)	• (EVOLVING)
• SPACE EFFECTS ON TELEOP. CAPABILITY	• (EVOLVING)	• (EVOLVING)
	• ZERO G MATERIALS HANDLING	• (EVOLVING)

PRE-IOC	IOC (92-97)	FOC (97-BEYOND)
• FAILURE DETECTION • FAILURE ISOLATION • FAULT TOLERANCE	• FAULT TOLERANT (EVOLVING) • FAULT REPAIR	• FAULT REPAIR (EVOLVING)
• ADVANCED AUTOMATION SOFTWARE ALGORITHMS	• REAL-TIME PLANNING • INDEPENDENT EXPERT	• INTERACTIVE AI/EXPERT SYSTEMS
• IMPROVED SATELLITE SERVICING TOOLS	• TELEOPERATOR SATELLITE SERVICING	• AUTONOMOUS SATELLITE SERVICING & REPAIR BY ROBOTS
	• ROBOTIC INSPECTION (SENSOR DEPENDENT)	• ROBOTS REPAIR BY ROBOTS
• WORKLOAD POWER CON-SUMPTION EXPERIMENTS		
• ROBOTIC VISION AND IMAGERY OPTIMIZATION	• SPACE EFFECTS ON VISION SYSTEMS	
• AUTONOMOUS ORBIT TRANSFER		
• COMPLIANCE TECHNIQUES	• (EVOLVING)	• (EVOLVING)
• MASS MOVEMENTS STUDIES	• MOMENTUM COORDINATION	• (EVOLVING)
• VOICE CONTROL/INTERACTION	• (EVOLVING)	• (EVOLVING)

AUTOMATION AND ROBOTICS

ACCOMMODATION ISSUES

- o "ROBOT FRIENDLY" INTERFACES FOR SERVICING, ASSEMBLY, AND DOCKING
- o STANDARD UTILITIES REQUIRED FROM MOBILITY SYSTEMS (RMS, MRMS, OMV, OTV, ETC.)
- o SAFETY
- o COMPUTING POWER, DATA STORAGE, SYSTEM ARCHITECTURES
- o STANDARDS FOR END EFFECTORS, ARMS, HOLDERS, ETC.
- o MASS/VOLUME MODEST
- o ASTRONAUT TRAINING REQUIRED
- o FORMATION FLYING REQUIRED
- o EVA NECESSARY IN SOME CASES
- o IVA ACTIVITY REQUIRED
- o HIGH BANDWIDTH VIDEO/ENCRYPTION COMMUNICATIONS SYSTEM

RECOMMENDATIONS

- ACCELERATE EXPERIMENT SCHEDULE - IMPACT SPACE STATION
- ACTIVE FOLLOW-UP TO EMBED TECHNOLOGY ACCOMMODATION ISSUES WITH SPACE STATION
- ESTABLISHMENT OF IN-SPACE TECHNOLOGY ADVOCACY COMMITTEE
- WORK WITH ULTIMATE USER GROUPS
- ENCOURAGE USERS TO COME FORWARD
- EXPLORE CREATIVE WAYS OF COST SHARING
- DEVELOP AND DISSEMINATE SPACE STATION IN-SPACE RESEARCH CAPABILITY
- BROADEN RESEARCH USER LIAISON WITH STATION
- COORDINATE BETWEEN PANELS - DISTRIBUTE TO PARTICIPANTS
- ESTABLISH CONTINUING MAIL LIST AND FOCAL POINTS

[illegible]
END

THEME

PRESENTATION

MATERIAL

OEX AAPS

(ADVANCED AUTOPILOT FOR SPACECRAFT)

E. BERGMANN
C.S. DRAPER LABORATORY

OEX AAPS (Advanced Autopilot for Spacecraft)

- OBJECTIVE:

Verify in flight advanced control concepts for reaction and momentum exchange control of spacecraft. Expected benefits include fuel optimality, coordinated translation and rotation for proximity operations, maximum fault tolerance, high adaptability to changes in vehicle configuration, combined use of reaction control and momentum exchange devices, learning/adaptive capability. and high level of autonomy. Vehicles such as Shuttle, OMV and Space Station are expected to benefit from this autopilot.

CSDL EVB

OEX AAPS (Advanced Autopilot for Spacecraft)

- Description

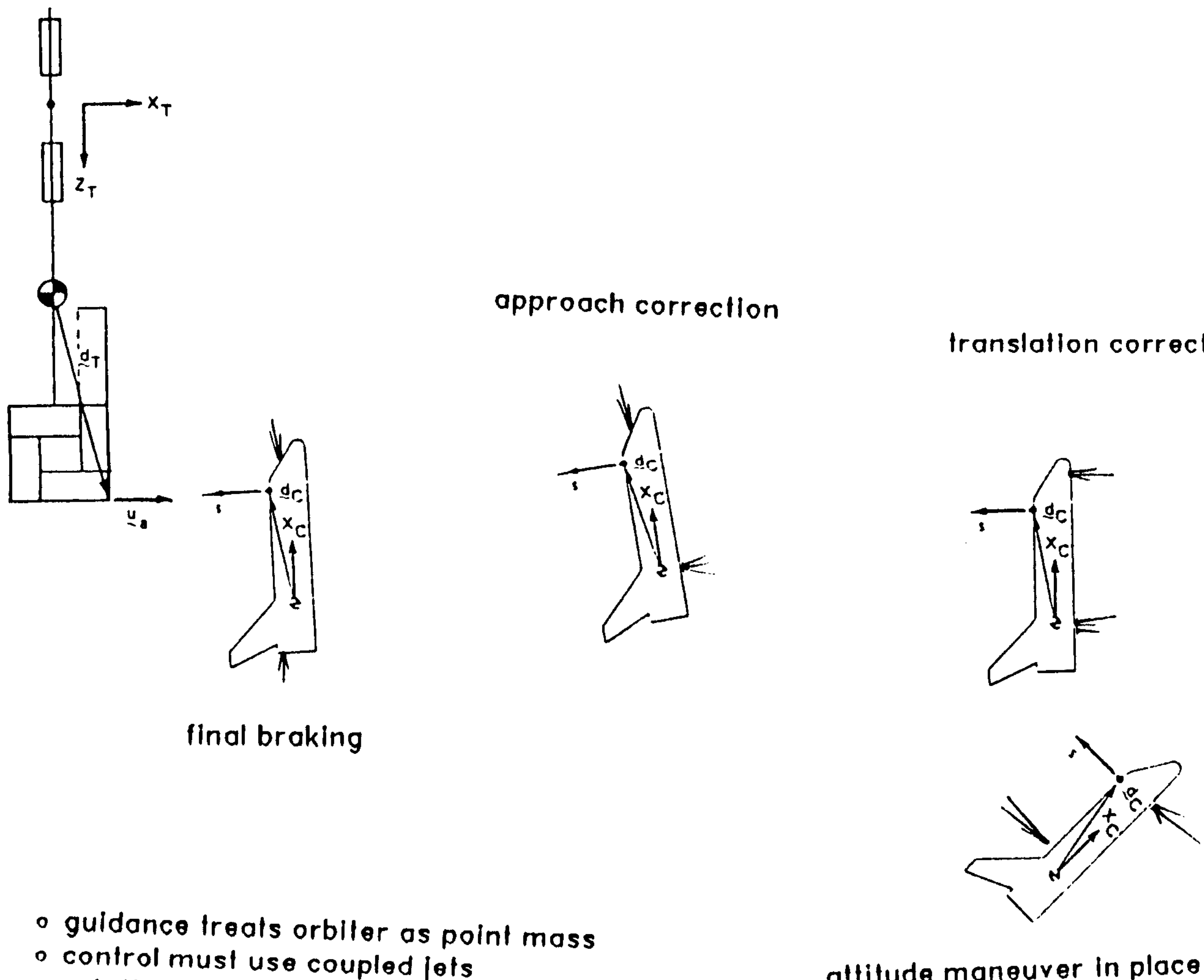
  A new phase space control law and optimal linear jet selection form the core of a proposed system for integrated optimal control of translation and rotation using combined momentum exchange and reaction control for proximity operations and for space station use. Recent successful flight tests of the phase space control law and optimal jet select on shuttle mission 51G (and planned for mission 61B) has confirmed the validity of the basic approach, indicating a high degree of adaptability, fault tolerance and fuel efficiency. Incorporation of the additional capabilities has been planned for in the initial implementation, and can be accomplished as upgrades to the existing system. An expert system is proposed for precise proximity operations which takes into account constraints, objectives, vehicle configuration and makes best use of resources available.

  The experimental system is implemented to be immediately available for operational use by the test vehicle, and easily portable to a broad class of spacecraft.

CSDL EVB

EXAMPLE: SHUTTLE DOCKING

Current Approach

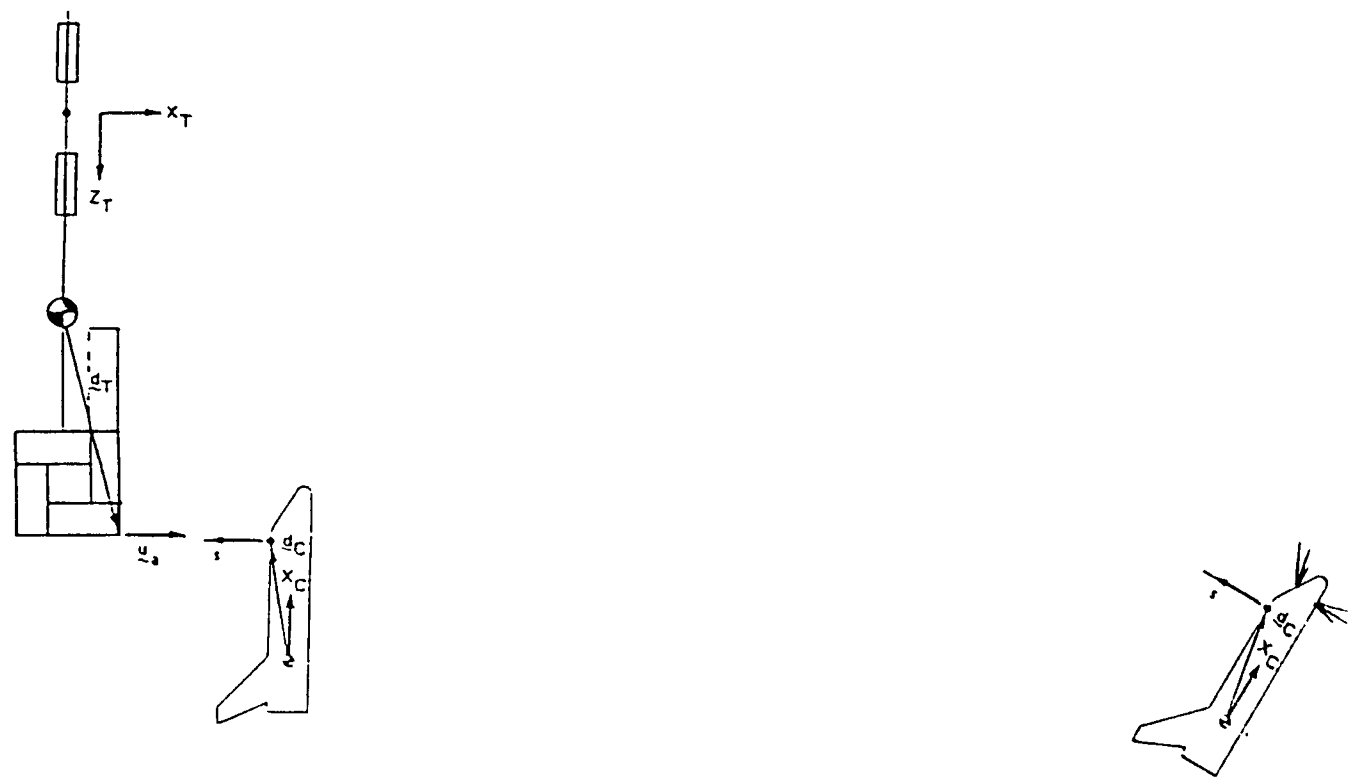


- guidance treats orbiter as point mass
- control must use coupled jets
- rotation, translation dynamics coupled

CSDL EVB

o EXAMPLE: SHUTTLE DOCKING

Proposed Approach



- o Advanced autopilot seeks 6 DOF trajectory
- o Fires optimal jets to establish trajectory
- o Trajectory designed to match final 6 DOF state
- o Substantial reduction in jet firings
- o Avoids plume impingement on target

CSDL EVB

ACCOMODATION REQUIREMENTS

EXPERIMENT TITLE: OEX ADVANCED AUTOPILOT

PROPOSED FLIGHT DATE - Phase I 1985 / Subsequent ~1990 YEAR

OPERATIONAL DAYS REQUIRED - 1/flight

MASS - Phase I - 0 / Subsequent TBD KG

VOLUME: N/A

STORED W ________ x L ________ x H ________ = ________ M3

DEPLOYED W ________ x L ________ x H ________ = ________ M3

INTERNALLY ATTACHED yes (YES/NO)
EXTERNALLY ATTCHED ________ (YES/NO)
FORMATION FLYING yes (YES/NO) (target)

ORIENTATION (inertial, solar, earth, other) various

EXTRA-VEHICULAR ACTIVITY REQUIRED:

0 Hrs/Day 0 No. of days.

INTRA-VEHICULAR ACTIVITY REQUIRED:

tbd Hrs/Day 1 No. of days

POWER REQUIRED:

________ KW AC or DC (circle one)

________ Hrs/Day ________ No. of days

DATA RATE: tbd Megabits/second

DATA STORAGE: -- Gigabits

EXPERIMENT

FLIGHT VS. GROUND COMMAND OF SERVICE ROBOT

F.E.BAKER

AUTOMATION & ROBOTIC
FLIGHT VS. GROUND COMMAND OF SERVICE ROBOT
EXPERIMENT OBJECTIVE

- EVALUATE ROBOT & OPERATOR CHARACTERISTICS OF ON-ORBIT SERVICE ROBOT OPERATION.
- TELEOPERATE SERVICE ROBOT USING COMMANDS ORGINATING IN PROXIMITY, ON ORBIT
- TELEOPERATE SERVICE ROBOT ON ORBIT USING COMMANDS ORIGINATING FROM A GROUND CONTROL STATION.
- EVALUATE RESULTS TO DETERMINE FEASIBILITY AND CHARACTERISTICS OF GROUND CONTROL OF SERVICE ROBOTS ON THE SPACE STATION AT IOC.
- EVALUATE CHARACTERISTICS OF OPERATOR/ROBOT TELEOPERATION INTERFACE INVOLVING PHYSICAL AND MECHANICAL ATTRIBUTES AT GROUND CONTROL STATION VS. ON ORBIT 0-G CONTROL STATION CONDITIONS.

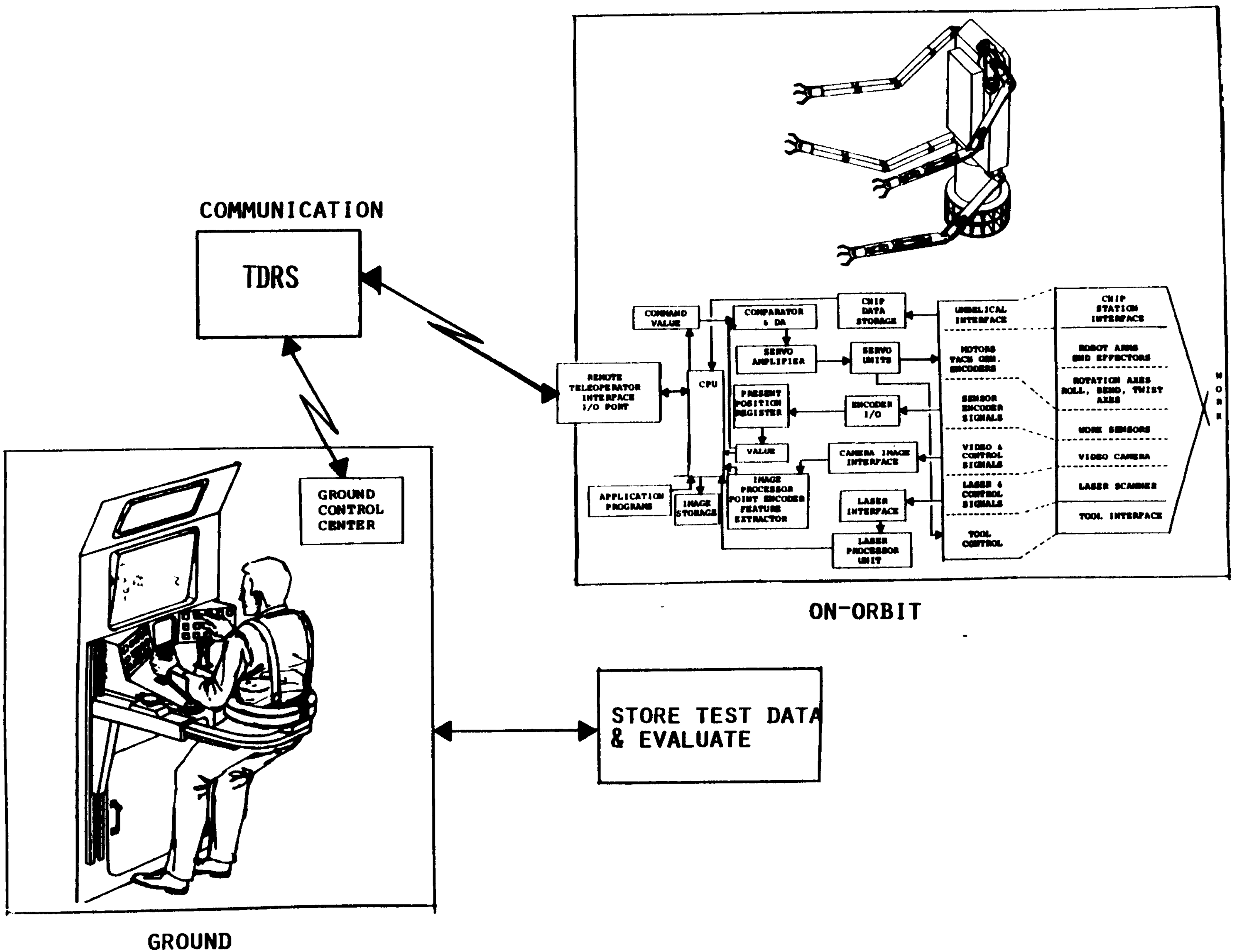
F.E. BAKER

AUTOMATION & ROBOTICS FLIGHT VS. GROUND COMMAND OF SERVICE ROBOT EXPERIMENT DESCRIPTION

- ALL ROBOT EXECUTION OF COMMANDS WOULD BE DIRECTED THROUGH A TELEOPERATION STATION.
- A COMMON SERVICE (20 FUNCTION) TASK WOULD BE USED FOR PROXIMITY CONTROL COMMANDS AND GROUND (TRANSMITTED) COMMANDS.
- TEST 1 - TRANSMIT COMMANDS (VIA TDRS) FROM GROUND CONTROL TELEOPERATION TO ORBITER ROBOT SYSTEM, PROCESS 20 STEP SCENARIO. RECORD ALL RESPONSE TIME & PERFORMANCE DATA IN FLIGHT AND AT GROUND SITE.
- TEST 2 - REPEAT EXACT COMMAND SCENARIO TO THE ROBOT USING ON-ORBIT TELEOPERATION SYSTEM. RECORD ALL RESPONSES TIME & PERFORMANCE DATA ABOARD ORBITER.
- EVALUATE ROBOT RESPONSE AND CHARACTERISTICS OF OPERATION ACTIONS, POSTURES AND EFFICIENCY OF TELEOPERATION CONTROL STATION CONFIGURATION.
- DETERMINE SPECIFIC PROGRAMMING REQUIREMENT DIFFERENCES BETWEEN GROUND TO ORBIT AND ON-ORBIT TELEOPERATION SYSTEMS CONTROL.

F.E. BAKER

GROUND CONTROL OF ON-ORBIT ROBOT SIMULATION SCHEMATIC



F.E. BAKER

EXPERIMENT TITLE: FLIGHT VS. GROUND COMMAND OF SERVICE ROBOT

PROPOSED FLIGHT DATE - 1990 YEAR

OPERATIONAL DAYS REQUIRED - ____

MASS - 200 KG

VOLUME:

STORED: W 1.3 M x L 1.3 M x H 1.3 M = 2.2 M^3

DEPLOYED: W ____ x L ____ x H ____ = ____ M^3

INTERNALLY ATTACHED YES (YES/NO)
EXTERNALLY ATTACHED N/A (YES/NO)
FORMATION FLYING N/A (YES/NO)

ORIENTATION (inertial, solar, earth, other) N/A

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: N/A Hrs/Day N/A No. of days

OPERATIONS: N/A Hrs/Day N/A No. of days N/A Interval

SERVICING: N/A Hrs/Day N/A No. of days N/A Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: .1 Hrs/Day ____ No. of days

OPERATIONS: 2 Hrs/Day 1 No. of days ____ Interval

SERVICING: .1 Hrs/Day 1 No. of days ____ Interval

POWER REQUIRED:

1 KW AC or DC (circle one)

2 Hrs/Day 1 No. of days

DATA RATE: 6 Megabits/second

DATA STORAGE: 22 Gigabits

TELEOPERATED STRUCTURES ASSEMBLY

RAYMOND WOO/DR. NEVILLE MARZWELL/JOHN MANKINS

OCTOBER 8-9-10, 1985

IN-SPACE RESEARCH, TECHNOLOGY & ENGINEERING
WORKSHOP

WILLIAMSBURG, VIRGINIA

EXPERIMENT OBJECTIVES

O TECHNOLOGY

- DEVELOP, DEMONSTRATE, AND EVALUATE ADVANCED TELEOPERATION TECHNIQUES IN SYSTEMATIC ASSEMBLY OF SPACE STRUCTURES.
- EVALUATE SMART SENSORS AND SPECIAL END EFFECTORS IN AN ORBIT ENVIRONMENT.
- ACQUIRE SPACE-BORNE DATA BASE FOR DEVISING STRATEGIES FOR EFFICIENT ASSEMBLY OF LFSS.

O SPACE STATION

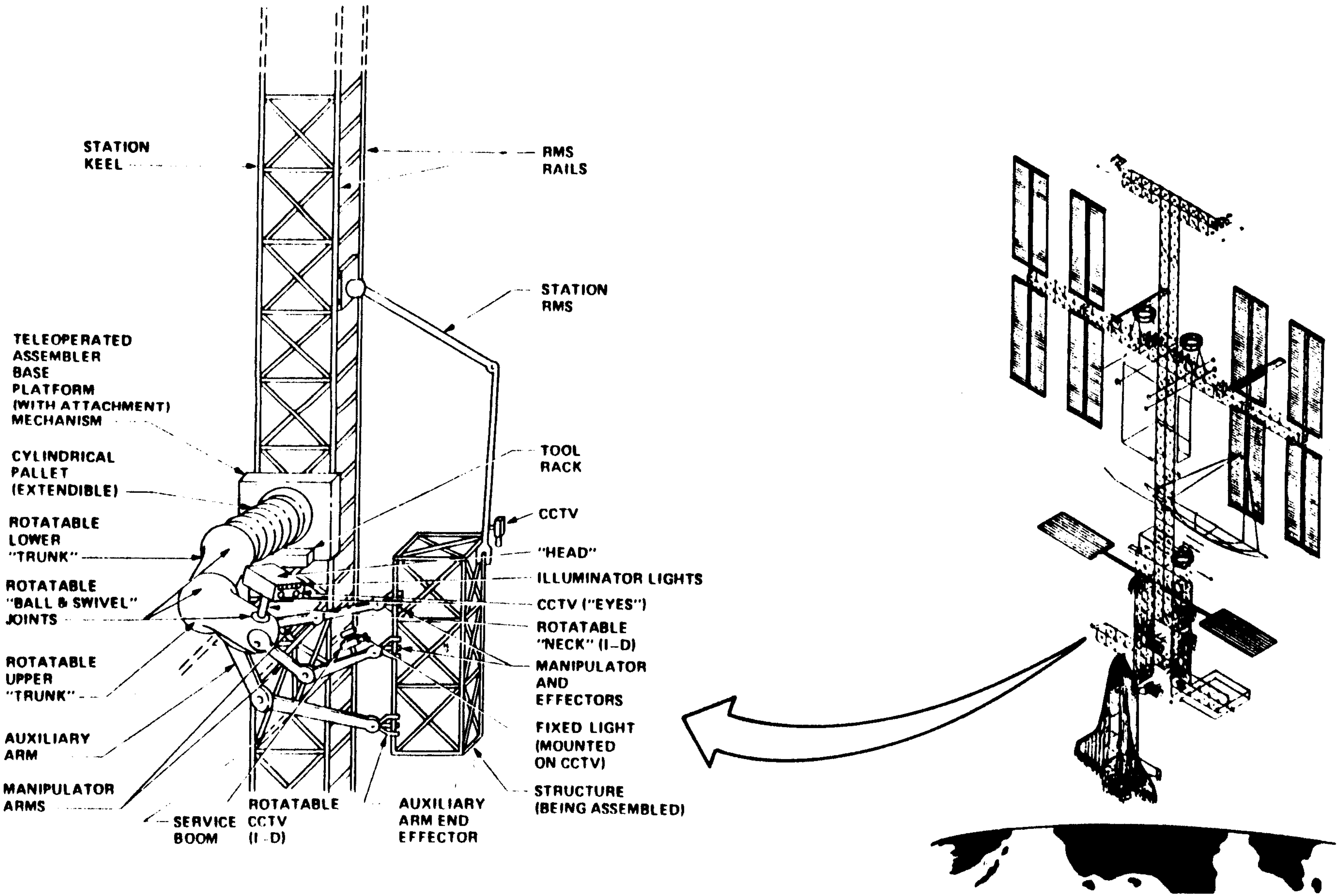
- PROVIDE TECHNOLOGY FOR TELEOPERATION CRITICAL TO FUNDAMENTALLY SUPPORT ACTIVITIES
- CHARACTERIZE SPECIALIZED FACILITIES SUPPORT FOR LARGE SCALE EXPERIMENTATION WITH SPACE STRUCTURES (POWER/THERMAL, COMMUNICATION, DATA PROCESSING, FLEXIBLE PAYLOAD ACCOMMODATIONS/STORAGE, MANPOWER).

- FLIGHT EXPERIMENT 1: TRUSS ASSEMBLY DEMONSTRATION
  - DEMONSTRATE AND EVALUATE ADVANCED TELEOPERATOR TECHNOLOGY/TECHNIQUES IN THE PERFORMANCE OF STRUCTURES ASSEMBLY IN AN ON-ORBIT ENVIRONMENT.
  - DEPLOY A SPECIALLY DESIGNED TELEOPERATED ASSEMBLER (TA) WITH THREE MANIPULATOR ARMS FOR ASSEMBLING STRUCTURES FROM TRUSS KITS.
  - THE TA MANIPULATOR ARMS WILL UNDER TELEOPERATED CONTROL PICK UP TRUSS MEMBERS FOR ASSEMBLY OF TRUSSES BY SNAPPING THEM TOGETHER.
  - THE TRUSSES WILL BE JOINED TO FORM A LARGE SPACE STRUCTURE.
  - UPON COMPLETION OF THE ASSEMBLY ACTIVITIES, THE SPACE STRUCTURE CAN BE DEPLOYED AS A PART OF GROWTH ON THE SPACE STATION OR BE DISASSEMBLED AND STORED.

- FLIGHT EXPERIMENT 2: TRUSS-MIRROR ASSEMBLY DEMONSTRATION
  - VERY SIMILAR TO THAT IN EXPERIMENT 1, EXCEPT THAT IN ADDITION MIRRORS WILL BE INSERTED INTO SPACES IN THE TRUSSES TO FORM A TRUSS-MIRROR STRUCTURE.
  - INVOLVES CLOSE COORDINATION OF THE 3 TA MANIPULATOR ARMS FOR SYSTEMATIC AND EFFICIENT TELEOPERATED ASSEMBLY OF THE TRUSS-MIRROR STRUCTURE.

JPL

TDMX 2461 TELEOPERATED STRUCTURE ASSEMBLY
(VOLUME 1)



ACCOMMODATION REQUIREMENTS

EXPERIMENT TITLE: TDMX 2461 - TELEOPERATED STRUCTURES ASSEMBLY

PRINCIPAL INVSTIGATOR(S): RAYMOND WOO/DR. NEVILLE MARZWELL

ADDRESS: BUILDING 198 ROOM 326

PROPOSED FLIGHT DATE 1992 YEAR(S)

OPERATIONAL DAYS REQUIRED 21 (PER YEAR)

MASS 2175. KG

VOLUME: 25.5 M^3

STORED W 3. x L 5. x H 1.7 = 25.5 M3

DEPLOYED W 2.5 x L 3. x H 4. = 30.0 M3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED YES (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) ______

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 2 Hrs/Day 1 No. of days.

OPERATIONS: ____ Hrs/Day ____ No. of days. ____ Interval

SERVICING: 4 Hrs/Day 2 No. of days. 30 Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 2 Hrs/Day 1 No. of days.

OPERATIONS: 9 Hrs/Day 7 No. of days. 30 Interval

SERVICING: ____ Hrs/Day ____ No. of days. ____ Interval

POWER REQUIRED:

1.0 KW AC or DC (circle one)

9 Hrs/Day 21 No. of days

DATA RATE: .09 Megabits/second

DATA STORAGE: .650 Gigabits

DEMONSTRATION OF DEXTEROUS TELEOPERATION TECHNOLOGY IN SUPPORT OF SPACE STATION OPERATIONS

RAYMOND WOO/DR. NEVILLE MARZWELL/JOHN MANKINS

OCTOBER 8-9-10, 1985

IN-SPACE RESEARCH, TECHNOLOGY & ENGINEERING WORKSHOP

WILLIAMSBURG, VIRGINIA

EXPERIMENT OBJECTIVES

O TECHNOLOGY

- DEVELOP, DEMONSTRATE, AND EVALUATE ADVANCED TELEOPERATION TECHNIQUES UTILIZING SMART SENSORS AND SPECIAL END EFFECTORS IN A SPACE-BORNE ENVIRONMENT.
- EVALUATE AND ASSESS PROPER MIX BETWEEN MANUAL AND AUTOMATIC CONTROL IN-SPACE TELEOPERATED ACTIVITIES.
- ACQUIRE SPACE-BORNE DATA BASE FOR IMPROVING END EFFECTORS, SMART SENSORS, AND TELEOPERATION SYSTEMS DESIGN.

O SPACE STATION

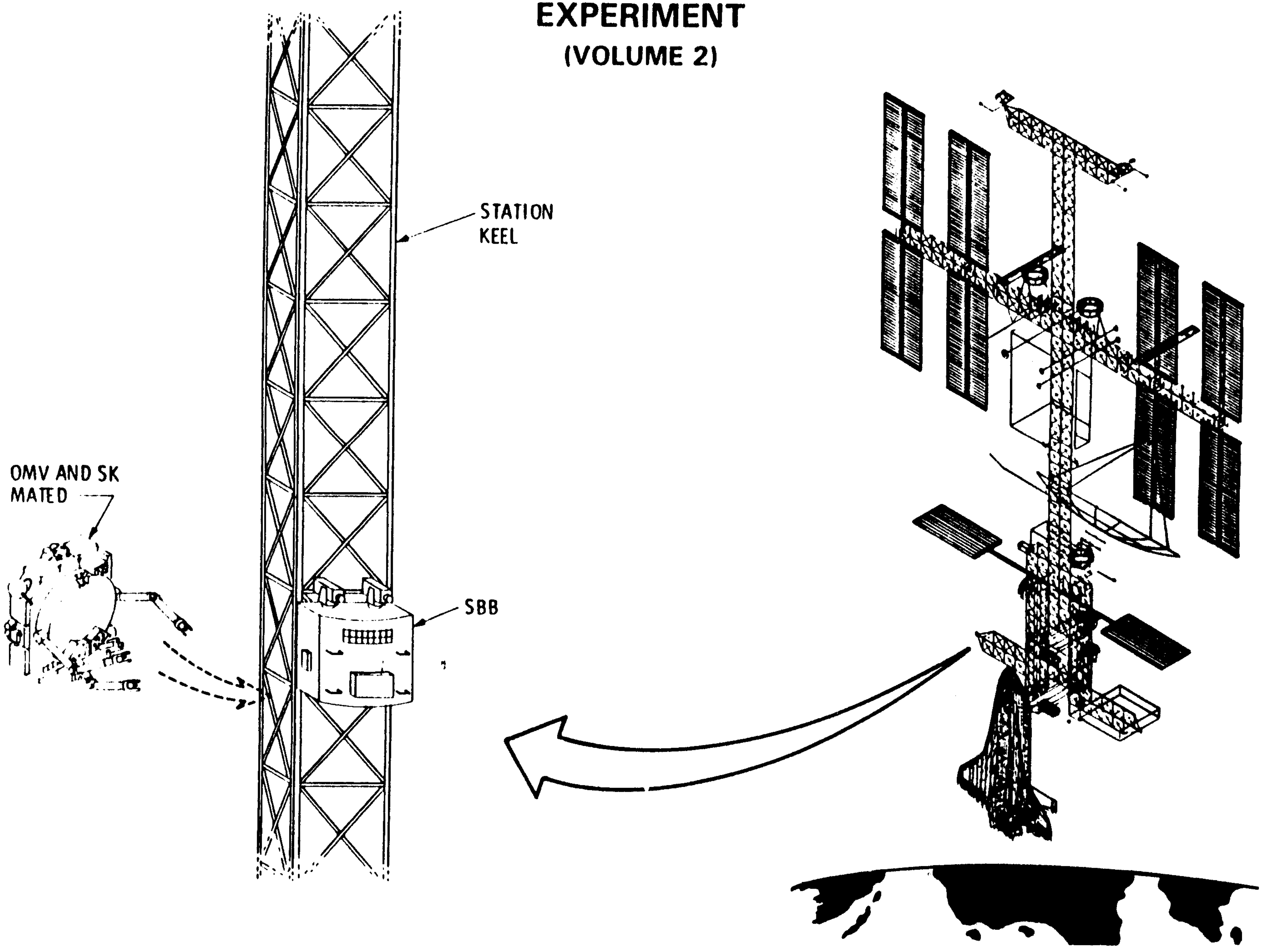
- PROVIDE OPERATION CAPABILITIES AND TRADE-OFF KNOWLEDGE OF TELEOPERATION IN SUPPORT OF SPACE STATION.
- CHARACTERIZE SPECIALIZED FACILITIES SUPPORT FOR LARGE SCALE EXPERIMENTATION WITH SPACE STRUCTURES (POWER/THERMAL, COMMUNICATION, DATA PROCESSING, FLEXIBLE PAYLOAD ACCOMMODATIONS/STORAGE, MANPOWER)

- FLIGHT EXPERIMENT 1: STATIONARY DEMONSTRATION
  - DEMONSTRATE AND EVALUATE ADVANCED TELEOPERATOR TECHNOLOGY IN THE PERFORMANCE OF DEXTEROUS TASKS IN WHICH A TELEOPERATED SERVICING UNIT WILL BE HAND ATTACHED TO THE MANIPULATOR BASE (E.G., SERVICING UNIT ATTACHED TO A SATELLITE IN NEED OF REPAIRS)
  - THE ORBITAL MANUEVERING VEHICLE (OMV) WILL DOCK AND MATE WITH A SPECIALLY DESIGNED SERVICER KIT (SK) WITH 3 MANIPULATOR ARMS.
  - THE OMV/SK UNIT WILL FLY TOWARD THE SATELLITE BUSY BOX (SBB), WHICH IS THE MANIPULATOR BASE FOR THE DEMONSTRATION.
  - THE SK WILL PERFORM DEXTEROUS MANIPULATIVE JOBS ON THE SBB WHILE BEING HARD ATTACHED TO IT.

- FLIGHT EXPERIMENT 2: DYNAMIC DEMONSTRATION
  - DEMONSTRATE AND EVALUATE ADVANCED TELEOPERATOR TECHNOLOGY IN THE PERFORMANCE OF DEXTEROUS TASKS IN WHICH A TELEOPERATED SERVICING UNIT WILL MAINTAIN REAL-TIME DYNAMIC STATIONKEEPING RELATIVE TO THE MANIPULATOR BASE (E.G. SERVICING UNIT CHASING AFTER A TUMBLING SATELLITE IN NEED OF REPAIRS).
  - THE OMV WILL DOCK AND MATE WITH THE SK AND THE OMV/SK UNIT WILL FLY TOWARD THE SBB.
  - THE OMV/SK UNIT WILL MAINTAIN REAL-TIME DYNAMIC STATIONKEEPING WITH THE SBB WHILE THE FORMER WILL PERFORM DEXTEROUS MANIPULATIVE JOBS ON THE LATTER.

JPL

TDMX 2462: DEXTROUS TELEOPERATOR TECHNOLOGY EXPERIMENT
(VOLUME 2)



ACCOMMODATION REQUIREMENTS

EXPERIMENT TITLE: TDMS 2462 - DEXTEROUS TELEOPERATOR TECHNOLOGY

PRINCIPAL INVSTIGATOR(S): RAYMOND WOO/DR. NEVILLE MARZWELL

ADDRESS: BUILDING 198 ROOM 326

PROPOSED FLIGHT DATE 1992 YEAR(S)

OPERATIONAL DAYS REQUIRED 60 (PER YEAR)

MASS 1975. KG

VOLUME: 13.5 M^3

STORED W 2 x L 2.7 x H 2.5 = 13.5 M3

DEPLOYED W 2 x L 4 x H 2 = 16.0 M3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED YES (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) ______

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	8	Hrs/Day	1	No. of days.		
OPERATIONS:		Hrs/Day		No. of days.		Interval
SERVICING:	4	Hrs/Day	2	No. of days.	30	Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	2	Hrs/Day	1	No. of days.		
OPERATIONS:	8	Hrs/Day	10	No. of days.	30	Interval
SERVICING:		Hrs/Day		No. of days.		Interval

POWER REQUIRED:

1.2 KW AC or DC (circle one)

4 Hrs/Day 60 No. of days

DATA RATE: .090 Megabits/second

DATA STORAGE: .650 Gigabits

ASTROMETRIC TELESCOPE FACILITY AUTONOMOUS OPERATION

IN—SPACE RT&E WORKSHOP

8—10 OCTOBER 1985

WILLIAMSBURG, VA

KENJI NISHIOKA

AMES RESEARCH CENTER

MOFFETT FIELD, CA 94035

EXPERIMENT OBJECTIVE:

Identify the requirements placed on the space station for the successful autonomous operation of the Astrometric Telescope Facility (ATF) on the space station and provide input to the space station program. In order to realize this primary objective, several key secondary objectives need to be realized, and they include the following: 1) Identification and definition of the key space station parameters that impact ATF autonomous operations; 2) Identification of bounds for the expected amplitudes and frequencies of the dynamic disturbances on the space station from station operations (station and payloads operations); 3) Definition of control algorithms that could be used for actively compensating for these disturbances by the ATF; 4) Identification of the format in which the key parameters will be provided by the space station to the ATF control algorithms for autonomous operations.

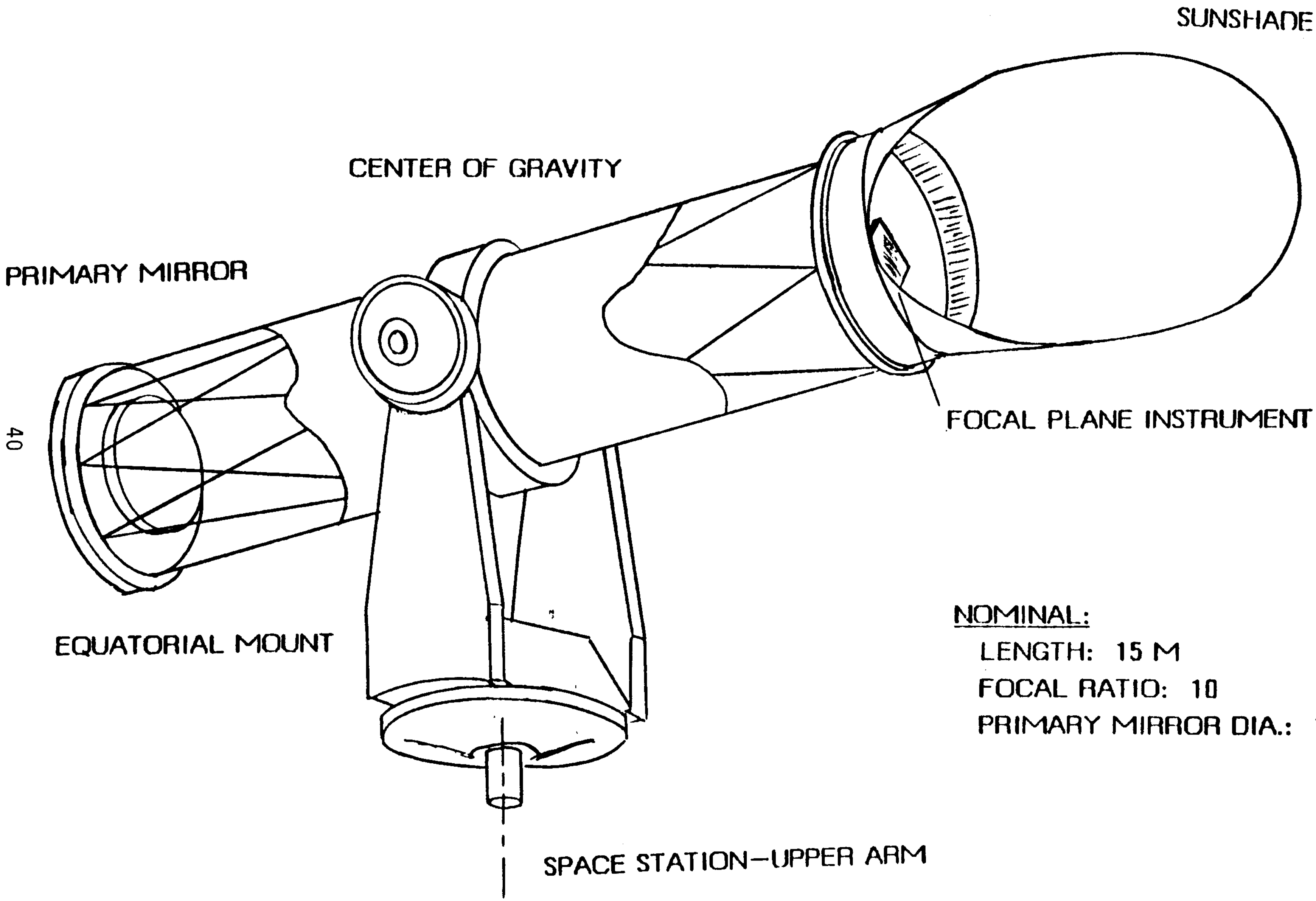
EXPERIMENT DESCRIPTION:

The Astrometric Telescope Facility (ATF) will be a longlife (10–20 years) Space Station payload and is expected to operate nearly continuously over this period making repeated observations of selected target stars to obtain star motion information so that stars with planetary systems can be identified. Approximately 100 stars will be observed over the experiment life. Because of the length and repetitive observations required in this program, automated or autonomous operations is a necessity to realize efficiency in operations and reasonable lifetime operations costs.

Orbital operations will be worked out on the ground and loaded into the ATF control computer. This procedure will be adequate if the space station was quiescent, but unfortunately there are dynamic oscillations due to other payloads and station activities. Some of these disturbances will be known because they will be scheduled activities and could be accounted for in the operations procedures but unfortunately there will be disturbances occurring randomly and the levels and frequencies of these disturbance will not be known. There are several ways in which the ATF could compensate for these dynamic disturbances, one approach would be to provide a passive vibration isolation mount for the ATF, a second would be to actively control motions of the mount or the telescope itself to compensate for the dynamic motions and a third could be active motion compensation of the image at the focal plane. In order to do the active compensation autonomously, the space station's disturbance parameters must be identified so that the control requirements can be defined and control algorithms developed. This study in FY 86 (if funded) will begin defining the requirements to make this process feasible by examining the ATF/Space Station interaction problem for the ATF by identifying and analysing the space station disturbances parametrically. The work will be continued in fiscal years 1987 through 1989 where the results of this FY 86 study will be used to develop design concepts for the hardware and software that will provide autonomous operation capability for the ATF on the Space Station.

The results from these studies will be specific to the ATF but the results should prove useful to other space station payloads interested in autonomous operation for lower operations costs.

SKETCH — ASTROMETRIC TELESCOPE FACILITY



NOMINAL:
LENGTH: 15 M
FOCAL RATIO: 10
PRIMARY MIRROR DIA.: 1.5 M

EXPERIMENT TITLE: Astrometric Telescope Facility - Autonomous Operation

PROPOSED FLIGHT DATE - 1994 YEAR

OPERATIONAL DAYS REQUIRED - 3650 - 7300

MASS - 3500 KG

VOLUME:

STORED: W 4.5 m - DIA x L 17.5 m x H 4.5 m - DIA = 278 M^3

DEPLOYED: W 4 m - DIA x L 17 m x H 5 m* = 214 M^3

INTERNALLY ATTACHED NO (YES/NO) * Mounting base height see figure
EXTERNALLY ATTACHED YES (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) Inertial

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: TBD Hrs/Day ______ No. of days

OPERATIONS: TBD Hrs/Day ______ No. of days ______ Interval

SERVICING: TBD Hrs/Day ______ No. of days ______ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: TBD Hrs/Day ______ No. of days

OPERATIONS: TBD Hrs/Day ______ No. of days ______ Interval

SERVICING: TBD Hrs/Day ______ No. of days ______ Interval

POWER REQUIRED:

2.5 KW AC or DC (circle one)

24 Hrs/Day 7300 No. of days

DATA RATE: 3 Megabits/second

DATA STORAGE: TBD Gigabits

B. Lockyear
NASA GSFC

TDM: ROBOT FOR SCIENCE LABORATORIES

OBJECTIVES: The objectives are to develop a space qualified robot containing both artificial intelligence and telerobotics capability with advanced sensors and manipulators. By control and supervision of life sciencs experiments and the utilization of artificially intelligent automation, the robot will be designed to minimize crew labor requirements for supporting these experiments. The robot will be demonstrated and tested in space via a Shuttle flight.

Throughout the experiment, emphasis will also be placed on the design of equipment compatible with the robot to minimize cost and maximize simplicity.

EXPERIMENT DESCRIPTION: The major components under study as shown in the enclosed block diagram are:

1. Robot with Manipulator(s)
2. Robot Controller
3. Attached and Fixed Sensors
4. Image/Sensor Processor
5. Expert System for Experiment (Operation) Control
6. Expert System for Observing "Technician"
7. Expert System for Process/Procedure Diagnosis
8. Communications Controller with External Gateway

Components 1 through 4 and 8 are physical units along with software, while components 5, 6, and 7 are software units but may require a separate processor to provide for their execution.

The robot, using its mobility which is provided either by rails or telescoping "legs", can position itself in the vicinity of a servicing area or test chamber. It then, by viewing the scene along with multisensor inputs, makes decisions as to required services/processes to be conducted. The "technician" ES takes notes and reports on progress while the other ES's plan, execute, and self diagnosis the appropriate operation. One of the simplest operations is the removal and/or replacement of modules with subsequent dispositon of the removed unit (perhaps it now is ready for stabilization and return to earth). Simultaneous with this operation, continuous full time monitoring via remote sensors (or fixed images) is conducted and the necessary electronic commands can be sent to experiments as needed.

TECHNOLOGY DEVELOPMENT MISSION

ROBOT FOR SCIENCE LABORATORIES

- PRESENTER: BRIAN LOCKYEAR
  GSFC CODE 735
  (301) 344-6451

- PROPOSER: RAY HARTENSTEIN
  GSFC CODE 735
  (301) 344-5659

- SPONSOR: STAN OLLENDORF
  GSFC CODE 700
  (301) 344-5228

EXPERIMENT OBJECTIVES

- TO DEVELOP A SPACE QUALIFIED ROBOT
  - ARTIFICIAL INTELLIGENCE
  - TELEROBOTICS
  - ADVANCED SENSORS & MANIPULATORS
- FOR USE IN MINIMIZING LABOR REQUIREMENTS IN SUPPORTING LIFE SCIENCES EXPERIMENTATION ON BOARD SPACE STATION
- DEMONSTRATE THE DEVELOPED TECHNOLOGY IN SPACE VIA A SHUTTLE FLIGHT
- DEMONSTRATE THE EFFECTIVENESS OF EQUIPMENT DESIGNED TO MATE EASILY WITH THE ROBOTS

POTENTIAL FUNCTIONS

- AUTOMATION
  - VIDEO FOR ANIMAL CAGES
  - NUTRIENT SYSTEM CONTROL
  - WASTE AND URINE SYSTEMS CONTROL
  - CLIMATE CONTROL
  - AUTOMATIC BTS TUNING
  - AUTOCORRELATION OF FLIGHT AND GROUND SPECIMEN DATA

- ROBOTICS
  - CHANGE OUT OF WASTE TRAYS
  - FIXATION OF PLANT AND ANIMAL SPECIMENS
  - BLOOD DRAW AND COLD STORAGE OF SPECIMENS

EXPERIMENT TITLE: Robot for Scienc Laboratories

PROPOSED FLIGHT DATE - 1989 YEAR

OPERATIONAL DAYS REQUIRED - ____________

MASS - 125 KG

VOLUME:

STORED: W 2 x L 2 x H 1 = 4 M^3

DEPLOYED: W ____ x L ____ x H ____ = ____ M^3

INTERNALLY ATTACHED Yes (YES/NO)
EXTERNALLY ATTACHED ____ (YES/NO)
FORMATION FLYING ____ (YES/NO)

ORIENTATION (inertial, solar, earth, other) ____________

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day ____ No. of days

OPERATIONS: 0 Hrs/Day ____ No. of days ____ Interval

SERVICING: 0 Hrs/Day ____ No. of days ____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ____ Hrs/Day ____ No. of days

OPERATIONS: ~1-2 Hrs/Day ____ No. of days ____ Interval
(may be ground monitoring)

SERVICING: ____ Hrs/Day ____ No. of days ____ Interval

POWER REQUIRED:

0.1 avg. KW AC or DC (circle one) (.2 KW peak)

24 Hrs/Day ____ No. of days

DATA RATE: 1 Megabits/second

DATA STORAGE: ____ Gigabits

Significant on-board storage is required within the robot system, however, little external storage is required - 100K bytes for statis/ops summary.

AUTOMATED SERVICING ROBOT

RAYMOND WOO/DR. NEVILLE MARZWELL/JOHN MANKINS

OCTOBER 8-9-10, 1985

IN-SPACE RESEARCH, TECHNOLOGY & ENGINEERING WORKSHOP

WILLIAMSBURG, VIRGINIA

EXPERIMENT OBJECTIVES

O TECHNOLOGY

- DEMONSTRATE THE CAPABILITY FOR AND POTENTIAL UTILITIES BEHIND THE DESIGN AND DEVELOPMENT OF A FULLY AUTOMATED PROTOTYPE SERVICING ROBOT.
- EVALUATE ITS PERFORMANCE IN ON-ORBIT OPERATIONS.

O SPACE STATION

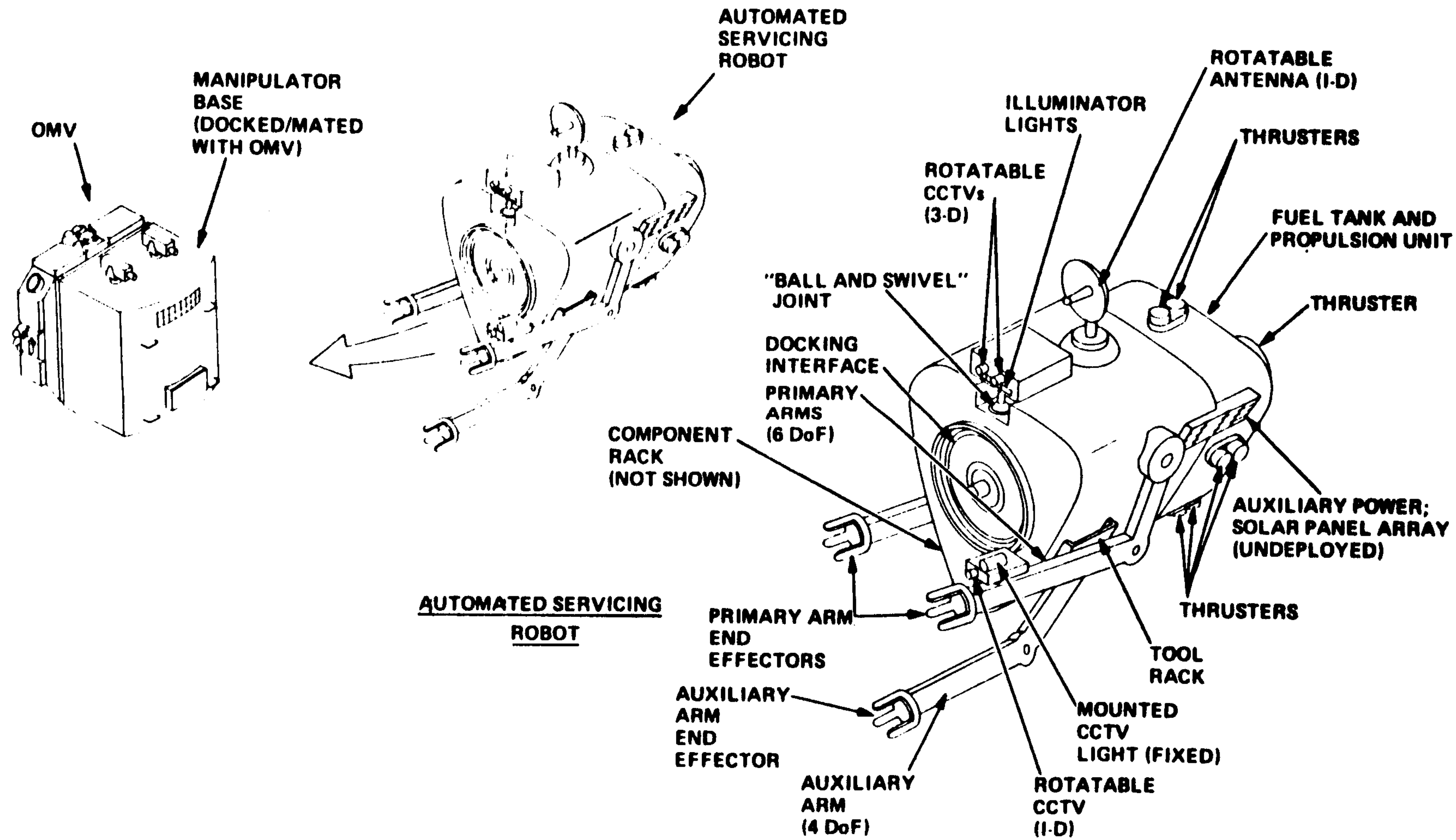
- SPACE STATION FACILITIES AND MANPOWER ARE NEEDED TO PROVIDE NEEDED FUNCTIONS FOR ASSESSING SERVICING ROBOT CAPABILITIES AND OPERATING REQUIREMENTS.
- IDENTIFY LIMITATION AND SERVICING FUNCTION TYPES FOR A SERVICING ROBOT.
- EVALUATE TECHNIQUES FOR STORAGE OF SERVICING ROBOT WHILE NOT IN USE AND ITS MAINTAINABILITY.
- CHARACTERIZED BY SPECIALIZED FACILITIES SUPPORT FOR LARGE SCALE EXPERIMENTATION WITH SPACE STRUCTURES (POWER/THERMAL, COMMUNICATION, DATA PROCESSING, FLEXIBLE PAYLOAD ACCOMMODATIONS/STORAGE, MANPOWER).

- FLIGHT EXPERIMENT 1: STATIONARY DEMONSTRATION
  - DEMONSTRATION AND EVALUATION OF THE AUTOMATED SERVICING ROBOT IN PERFORMING DEXTEROUS JOBS IN A STATIONARY MODE RELATIVE TO THE MANIPULATOR BASE.
  - THE SERVICING ROBOT WILL FLY TO THE MANIPULATOR BASE (WHICH IS LOCATED ON THE SPACE STATION) AND ATTACH ITSELF TO THE LATTER.
  - UPON FIRM ATTACHMENT TO THE MANIPULATOR BASE, THE SERVICING ROBOT WILL PERFORM DEXTEROUS JOBS SUCH AS ENGAGING HARD POINT, SCREWING, LATCHING, MODULE REMOVAL/REPLACEMENT, VISUAL INSPECTION, AND DIAGNOSTICS.

- FLIGHT EXPERIMENT 2: DYNAMIC DEMONSTRATION
  - DEMONSTRATION AND EVALUATION OF THE AUTOMATED SEVICING ROBOT IN PERFORMING DEXTEROUS JOBS IN A DYNAMIC STATIONKEEPING MODE RELATIVE TO THE MANIPULATOR BASE.
  - THE SERVICING ROBOT WILL FLY TO THE MANIPULATOR BASE AND MAINTAIN REAL-TIME STATIONKEEPING RELATIVE TO IT. THIS IS REPRESENTATIVE OF A TYPICAL SITUATION IN WHICH THE SERVICING ROBOT WILL CHASE AFTER A TUMBLING SATELLITE THAT NEEDS REPAIRS.
  - UPON ACQUISITION OF REAL-TIME DYNAMIC STATIONKEEPING, THE SERVICING ROBOT WILL PERFORM DEXTEROUS JOBS VERY SIMILAR TO THOSE OF THE STATIONARY DEMONSTRATION.

JPL

TDMX: AUTOMATED SERVICING ROBOT EXPERIMENTATION OVERVIEW—ILLUSTRATED



ACCOMMODATION REQUIREMENTS

EXPERIMENT TITLE: TDMX - AUTOMATED SERVICING ROBOT

PRINCIPAL INVSTIGATOR(S): RAYMOND WOO/DR. NEVILLE MARZWELL

ADDRESS: BUILDING 198 ROOM 326

PROPOSED FLIGHT DATE 1997 YEAR(S)

OPERATIONAL DAYS REQUIRED 60 (PER YEAR)

MASS 2000. KG

VOLUME: 14.0 M^3

	W		x L		x H		=		
STORED	W	3.5	x L	2	x H	2	=	14.0	M3
DEPLOYED	W	2.5	x L	2	x H	3	=	15.0	M3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED NO (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) ____

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	8	Hrs/Day	1	No. of days.		
OPERATIONS:		Hrs/Day		No. of days.		Interval
SERVICING:	4	Hrs/Day	2	No. of days.	30	Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	2	Hrs/Day	1	No. of days.		
OPERATIONS:	8	Hrs/Day	15	No. of days.	30	Interval
SERVICING:		Hrs/Day		No. of days.		Interval

POWER REQUIRED:

1.0 KW AC or DC (circle one)

8 Hrs/Day 60 No. of days

DATA RATE: .090 Megabits/second

DATA STORAGE: .650 Gigabits

DYNAMICS OF RETARGETING AND MANEUVERING
OF LARGE SPACE STRUCTURES

RAYMOND WOO/DR. NEVILLE MARZWELL/JOHN MANKINS

OCTOBER 8-9-10, 1985

IN-SPACE RESEARCH, TECHNOLOGY & ENGINEERING
WORKSHOP

WILLIAMSBURG, VIRGINIA

EXPERIMENT OBJECTIVES

O TECHNOLOGY

- DEVELOP METHODOLOGY FOR MEASUREMENT OF DYNAMICAL CHARACTERISTICS OF LFSS INVOLVED DURING MANEUVERS AND TRANSPORTATION.
- IDENTIFY STRATEGIES AND TECHNIQUES FOR EFFICIENT TRANSPORTATION AND MANEUVERING OF LARGE STRUCTURES AND STRUCTURAL COMPONENTS FOR GROWTH, MODIFICATION OR RECONFIGURATION OF LARGE STRUCTURAL SYSTEMS.
- DEMONSTRATE FEASIBILITY OF UNMANNED ORBITING PLATFORMS.

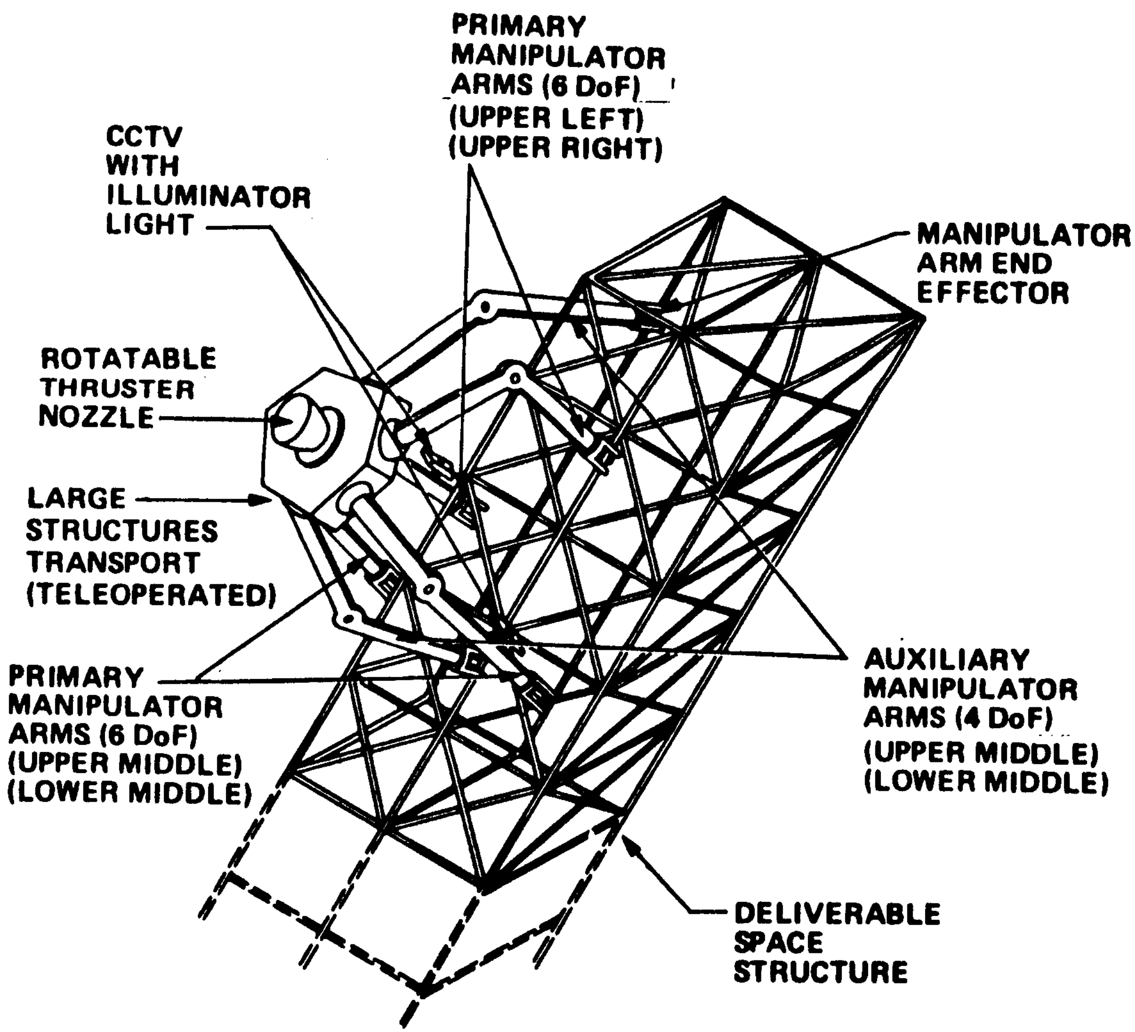
O SPACE STATION

- DEMONSTRATE THAT LARGE MASSIVE STRUCTURES AND STRUCTURAL COMPONENTS CAN BE STORED AND ASSEMBLED/DISASSEMBLED IN AN ON-ORBIT ENVIRONMENT.
- IDENTIFY LIMITATION/REQUIREMENTS FOR LFSS TO BE TRANSPORTED FROM POINT TO POINT, RECONFIGURATION OR MODIFICATION OF SPACE STATION ELEMENTS.
- CHARACTERIZE SPECIALIZED FACILITIES SUPPORT FOR LARGE SCALE EXPERIMENTATION WITH SPACE STRUCTURES (POWER/THERMAL, COMMUNICATION, DATA PROCESSING, FLEXIBLE PAYLOAD ACCOMMODATIONS/STORAGE, MANPOWER).

- FLIGHT EXPERIMENT 1: BASIC TOWING AND MANEUVERS
  - TRANSPORT SPACE TRUSSES AND SOLAR PANELS USING A LARGE STRUCTURES TRANSPORT.
  - CONDUCT MEASUREMENTS OF FORCE AND TORQUES INVOLVED IN THE TRANSPORTATION PROCESS, AND DETERMINE THE MANEUVERS AND TRANSPORT STRATEGIES THAT WILL ENHANCE AND MAXIMIZE THE SAFETY AS WELL AS PRESERVE OR MAINTAIN THE DYNAMIC STABILITY OF THE OBJECTS BEING TOWED.
  - THE SPACE TRUSSES AND SOLAR PANELS WILL BE DELIVERED AT THE END OF THE EXPERIMENT TO DESIGNATED POINTS ON THE STATION FOR FIRM ATTACHMENT OR FOR DISASSEMBLY AND STORAGE.

- FLIGHT EXPERIMENT 2: LARGE STRUCTURE MANEUVERS
  - PREPARE A LARGE DEPLOYABLE PACKAGE/PAYLOAD, E.G. DEPLOYABLE ANTENNA PALLET, ON THE SPACE STATION FOR DELIVERY TO A HIGHER ORBIT.
  - DEPLOY A LARGE STRUCTURES TRANSPORT THAT IS SPECIALLY DESIGNED AS CARRIER/TRANSPORT UNIT FOR LARGE STRUCTURES.
  - DELIVER THE LARGE STRUCTURE AS AN EXTERNALLY CARRIED PAYLOAD TO A DESIGNATED ORBIT.
  - CONDUCT MEASUREMENTS OF FORCES AND TORQUES INVOLVED IN THE DELIVERY PROCESS, AND DETERMINE THE TECHNIQUES OF TRANSPORTING AND/OR MANEUVERING THAT EFFECTIVELY MAXIMIZE AND ENHANCE TRANSPORTATION CONTROL AND SAFETY IN ADDITION TO MAINTAINING THE DYNAMIC STABILITY OF THE DELIVERABLE STRUCTURE.
  - THE LARGE STRUCTURES TRANSPORT MAY BE DEPLOYED AT THE DESIGNATED ORBIT, OR THE DEPLOYABLE PAYLOAD/PACKAGE RETURNED TO THE SPACE STATION FOR STORAGE OR DEPLOYMENT IN THE VICINITY.

JPL TDMX: DYNAMICS OF RETARGETING AND MANEUVERING OF LARGE STRUCTURES EXPERIMENTATION OVERVIEW—ILLUSTRATED



ACCOMMODATION REQUIREMENTS

EXPERIMENT TITLE: TDMX - DYNAMICS OF RETARGETING AND MANEUVERING OF LARGE SPACE STRUCTURES

PRINCIPAL INVSTIGATOR(S): RAYMOND WOO/DR. NEVILLE MARZWELL

ADDRESS: BUILDING 198 ROOM 326

PROPOSED FLIGHT DATE 1993 YEAR(S)

OPERATIONAL DAYS REQUIRED 60 (PER YEAR)

MASS 2200. KG

VOLUME: 27.0 M^3

STORED W 3. x L 3. x H 3. = 27.0 M3

DEPLOYED W 4. x L 2 x H 4. = 32.0 M3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED NO (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) ______

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	8	Hrs/Day	1	No. of days.		
OPERATIONS:		Hrs/Day		No. of days.		Interval
SERVICING:	4	Hrs/Day	2	No. of days.	30	Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	2	Hrs/Day	1	No. of days.		
OPERATIONS:	9	Hrs/Day	15	No. of days.	30	Interval
SERVICING:		Hrs/Day		No. of days.		Interval

POWER REQUIRED:

1.0 KW AC or DC (circle one)

9 Hrs/Day 60 No. of days

DATA RATE: .09 Megabits/second

DATA STORAGE: .650 Gigabits

HUMAN-MACHINE INTERFACE WORKLOAD

JOHN D. HESTENES

October 8-9-10, 1985

In-Space Research, Technology & Engineering Workshop

- ***EXPERIMENT OBJECTIVE:***

The long range objective is a capability to make reproducible, non-invasive measurements of cognitive and perceptual function during task performance in the Space Station environment.

The experiment will test the use of a Neuromagnetometer Array Instrument to measure human-dependent parameters in several human-machine work stations, including the Teleoperator Operator Workstation. Data is to be obtained on-line while varying task workload.

The resulting data will be used to understand human workload, strategies and allocation of attention. The effects of long duration space flight on cognitive and perceptual function will be used to assess human-machine interface designs and crew workload management.

• EXPERIMENT DESCRIPTION

Measurements recorded by a neuromagnetometer will be performed during the normally scheduled tasks with the Teleoperator Workstation or other selected workstations. An advanced neuromagnetometer workstation will be used for calibrations and special studies. Studies will be performed 10 days per month for one year by 4 operators. Each session is 2 hours after a set-up time for instrument stabilization.

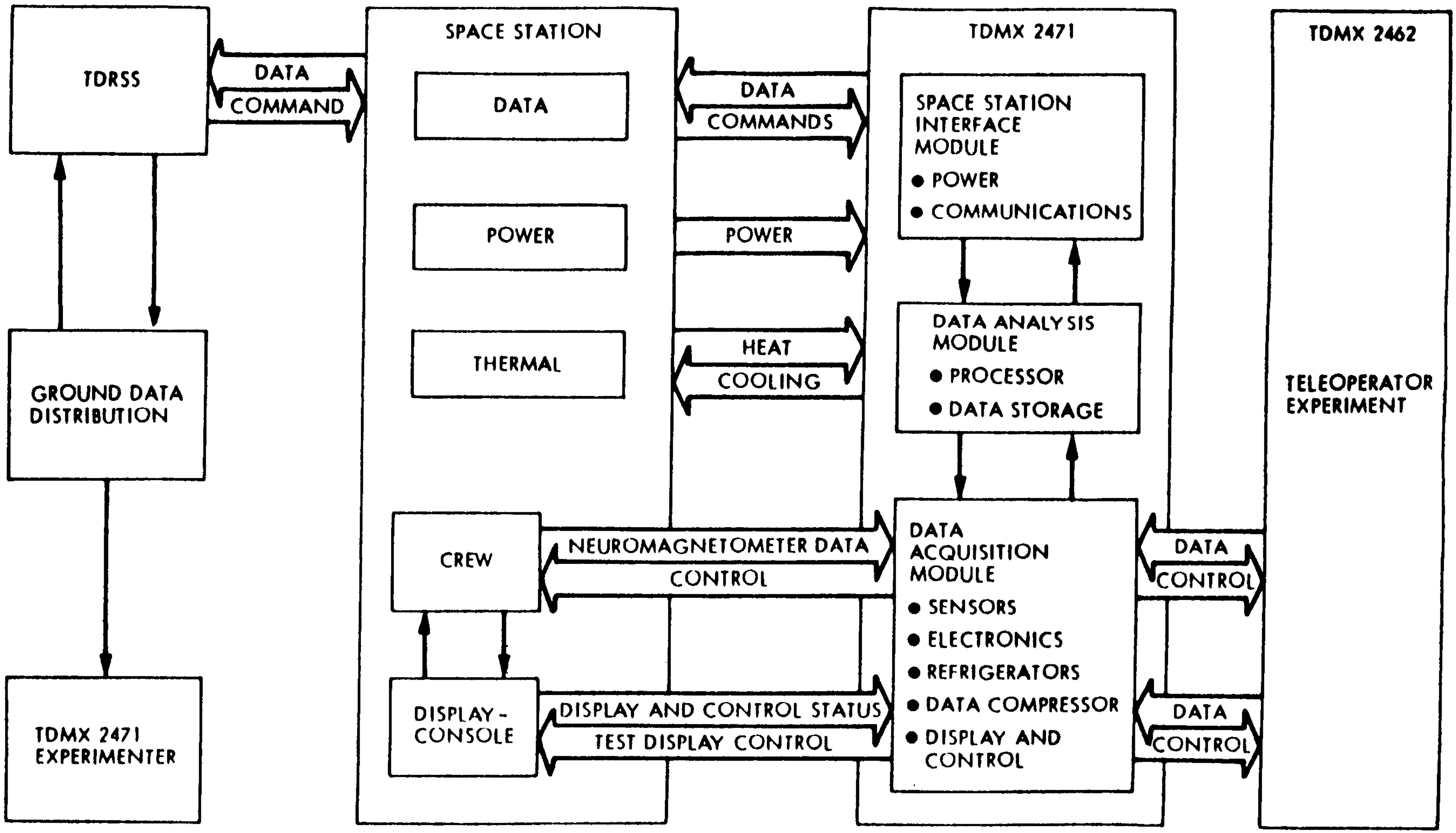
The data captured include synchronization signals (keystrokes, events), workstation display data, and display format. Some display features are controlled to evoke neuromagnetic response events in a synchronized manner. Task difficulty will be either as encountered during normal tasks or will be controlled over a range of difficulties. Allocation of attention during display and control sequences will be measured.

A ground-based experimenter monitors the task, selects task sequences and initiatiates experimental and data reduction options. Alternative tasks will be downloaded as indicated. A second crew member may assist while the observer is performing the task. Data is partially reduced on-line.

Between Teleoperator operational sessions the oberver is calibrated and performs advanced experiments using a special neuromagnetometer workstation. Experiments are performed over several months to assess long term effects of the microgravity environment on workload and allocation of attention. The results will be used to verify the usefulness and effectiveness of displays, controls and task procedures for various tasks at the workstations. Adaptive interfaces and crew workload management issues will be studied.

JPL

TDMX 2471: HUMAN-MACHINE INTERFACE WORKLOAD (VOLUME 13)



ACCOMODATION REQUIREMENTS

EXPERIMENT TITLE: HUMAN-MACHINE INTERFACE WORKLOAD

PRINCIPAL INVESTIGATOR: John D. Hestenes, Ph.D.

ADDRESS: Jet Propulsion Lab, Pasadena CA

PROPOSED FLIGHT DATE 1993-4 (One year)

OPERATIONAL DAYS REQUIRED 120 over 1 year period

MASS 500 KG

VOLUME:

STORED	W	.5	x L 1	x H 2	= 1	M3
DEPLOYED	W	1.5	x L 2	x H 2	= 6	M3

INTERNALLY ATTACHED NO (YES/NO) (Attach to Teleoperator Workstation)
EXTERNALLY ATTACHED NO (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) Any

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: NONE Hrs/Day No. of days.

OPERATIONS: NONE Hrs/Day No. of days. Interval

SERVICING: NONE Hrs/Day No. of days. Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 2 Hrs/Day 120 No. of days.

OPERATIONS: 4 Hrs/Day 120 No. of days. 10/Month Interval

SERVICING: 1 Hrs/Day 4 No. of days. Quarterly Interval

POWER REQUIRED:

.2 KW DC

18 Hrs/Day 120 No. of days.

DATA RATE: 10 Megabits/second

DATA STORAGE: .2 Gigabits

SPACE POWER SYSTEMS

AUTOMATION AND ROBOTICS SPACE EXPERIMENTS

IN SPACE RESEARCH, TECHNOLOGY,
AND ENGINEERING WORKSHOP.
WILLIAMSBURG, VIRGINIA.
OCTOBER 8 - 10, 1985

KARL A. FAYMON
POWER TECHNOLOGY DIVISION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO.

SPACE POWER SYSTEMS: AUTOMATION AND ROBOTICS SPACE EXPERIMENTS

OBJECTIVE:

TO VERIFY AUTONOMOUS OPERATION OF A SOLAR SPACE POWER SYSTEM - AND TO DEMONSTRATE TELEOPERATOR AND AUTONOMOUS REPAIR FUNCTIONS FOR A SPACE POWER SYSTEM ON THE SPACE STATION POWER SYSTEM TEST BED.

DESCRIPTION:

THE AUTONOMOUS OPERATION OF A SOLAR SPACE POWER SYSTEM WILL BE INITIALLY DEMONSTRATED ON A GROUND TEST BED BY THE MID 90'S.

- COMPLETE SYSTEM UNDER THE CONTROL OF AN EXECUTIVE CONTROLLER
- WILL INCLUDE REAL AND SIMULATED LOAD PROFILES
  - NORMAL AND AUTONOMOUS OPERATING CONDITIONS TO SIMULATE FAULTS
- PRECURSOR SHUTTLE EXPERIMENTS WILL BE CARRIED OUT FOR THOSE ELEMENTS OF THE POWER SYSTEM REQUIRING ZERO-G VERIFICATION

THE SPACE STATION TEST WILL PROVIDE A PROOF OF CONCEPT VERIFICATION

- EXTENDED OPERATION IN THE SPACE ENVIRONMENT

THE SPACE POWER SYSTEM WILL BE DESIGNED TO A MODULARITY CONCEPT

- TO ENABLE REPLACEMENT AND REPAIR OF FAILED UNITS
  - TELEOPERATOR OR "ROBOT REPAIRMAN" OPERATION
  - AUTOMATED FAILED COMPONENT ISOLATION

POWER SYSTEM AUTONOMOUS OPERATION DEMONSTRATION

THE FUNCTIONS TO BE PERFORMED ARE:

- RESOURCE MANAGEMENT
  - ENERGY CONVERSION/ENERGY STORAGE SYSTEM
  - LOAD MANAGEMENT
  - SOLAR ORIENTATION AND CONTROL
- SYSTEM MONITORING
  - SUBSYSTEM/COMPONENT STATE ESTIMATION
  - SUBSYSTEM/COMPONENT PERFORMANCE TREND PREDICTION
  - FAULT DETECTION/FAULT ISOLATION
  - SYSTEM RESTORATION

RELATED TDM'S

TDM 2111. DEPLOYMENT AND TESTING OF LARGE SOLAR CONCENTRATORS
2152. LARGE SPACE POWER SYSTEMS TECHNOLOGY
2153. SOLAR DYNAMIC TEST FACILITY
2143. DYNAMIC DISTURBANCES
2411. ADVANCED ADAPTIVE CONTROL
2442. ADVANCED AUTOMATION TECHNOLOGY

TELEOPERATOR-ROBOTIC REPAIR OF SYSTEMS COMPONENTS

THE FUNCTIONS TO BE PERFORMED ARE:

- MAINTENANCE SCHEDULING
  - INSPECTION/PERFORMANCE PREDICTION
  - REPAIR/REPLACEMENT SCHEDULING
- REPAIR-REPLACEMENT OF FAILED UNITS
  - AUTOMATED UNIT ISOLATION
  - TELEOPERATOR CONTROLLED
  - AUTOMATED/ROBOT REPAIRMAN APPLICATIONS

RELATED TDM'S

TDM 2063. ON ORBIT SPACECRAFT ASSEMBLY TEST
2461. STRUCTURAL ASSEMBLY IN SPACE
2462. TELEOPERATOR SENSORS - EVALUATION & TESTING
2131. RADIATOR TECHNOLOGY (REPAIR)

SUMMARY

- THE SYSTEM TO BE TESTED IN SPACE WILL BE A SMALL >10K SOLAR THERMAL POWER SYSTEM (ACTUAL SYSTEM TBD)
- OPERATIONAL AND DESIGN DATA WILL BE OBTAINED FROM
  - RELATED TDM'S
  - OAST AUTOMATION AND ROBOTICS DEMONSTRATION PROGRAM
  - LDR TECHNOLOGY PROGRAM
  - ETC.

EXPERIMENT TITLE: SPACE POWER SYSTEMS: A&R SPACE EXPERIMENTS

PROPOSED FLIGHT DATE - Mid-Late 90's YEAR

OPERATIONAL DAYS REQUIRED - TBD

MASS - 400 KG

VOLUME:

STORED: W 10M D x L 7M x H - = 70 M^3

DEPLOYED: W 12M DIAM x L - x H 5M = 60 M^3

INTERNALLY ATTACHED No (YES/NO)
EXTERNALLY ATTACHED Yes (YES/NO)
FORMATION FLYING No (YES/NO)

ORIENTATION (inertial, solar, earth, other) Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of days

OPERATIONS: 1 Hrs/Day 3 No. of days 30 Interval

SERVICING: 1 Hrs/Day 3 No. of days 30 Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 8 Hrs/Day 2 No. of days

OPERATIONS: 11 Hrs/Day 3 No. of days 30 Interval

SERVICING: 1 Hrs/Day 3 No. of days 30 Interval

POWER REQUIRED:

1 KW TBD ~~AC or DC~~ (circle one)

24 Hrs/Day TBD No. of days

DATA RATE: TBD Megabits/second

DATA STORAGE: TBD Gigabits

NEAR-TERM TELEOPERATOR MANEUVERING EXPERIMENT

Purpose:

To investigate manual control of a free-flying vehicle in proximity maneuvering tasks typical of space station operations

Objectives:

To design a near-term experiment, with maximum use of existing hardware, which will provide data during the design phase of Space Station/OMV

Originator:

Prof. David L. Akin
M.I.T. Space Systems Lab
Massachusetts Institute of Technology
Cambridge, MA 02139

NEAR-TERM TELEOPERATOR MANEUVERING EXPERIMENT

Experiment Description:

Methodology	Fly docking approaches using MMU to compare manual (EVA) with teleoperated maneuvering in docking task.
Hardware	One MMU (STS standard) with TPAD (41-B/C), flown by EVA crewman. One MMU (modified) with RF command link to AFD, EMU-TV (STS standard), TPAD. Approaches flown to MMS trunnion pin (41-B) mounted to RMS grapple fixture (STS standard).
Test Matrix	Docking approaches flown by EVA crewman in MMU. Approaches repeated by teleoperated MMU flown from Aft Flight Deck. Data via video/film stereo reconstruction, telemetry as available
Augmentations	Repeat EVAs to increase subject pool; docking pin on free-flying SPAS; variable time delays in control loop
Correlation	Neutral buoyancy; motion carriage; air-bearing floor

NEAR-TERM TELEOPERATOR MANEUVERING EXPERIMENT

Maneuvering Vehicle:

- Manned Maneuvering Unit with hand controllers removed
- RF command system integrated to MMU through EMU PLSS latches (mechanical) and hand controller connectors (electrical). Commands given to standard MMU flight control system using hand controller communications protocol
- Video system is standard EMU-TV mounted to command system enclosure, using Orbiter standard video displays and controls
- Docking system is TPAD, with standard interfaces to MMU arms
- System is checked out, released, and reberthed by EVA crewman
- Docking approaches flown to MMS trunnion pin on grapple fixture held by extended RMS (safe separation distance)

NEAR-TERM TELEOPERATOR MANEUVERING EXPERIMENT

Proposed Flight Date	1988
Operational Days Required	3 (2 EVA's)
Mass	2 MMUs with FSS
Volume	2 MMUs with FSS
Internally attached	
Externally Attached	✓
Formation Flying	✓ (under human control)
Orientation	N/A
EVA Required	✓
Set-up	STS-standard
Operations	6 hours/day 2 days
Servicing	STS-standard
IVA Required	✓
Set-up	A/R
Operations	6 hours/day 2 days
Servicing	None
Power	TBD
Data Rate	TBD
Data Storage	TBD

BERTHING/DOCKING MECHANISMS
AND CONTROLS

RAYMOND WOO/DR. NEVILLE MARZWELL/JOHN MANKINS

OCTOBER 8-9-10, 1985

IN-SPACE RESEARCH, TECHNOLOGY & ENGINEERING
WORKSHOP

WILLIAMSBURG, VIRGINIA

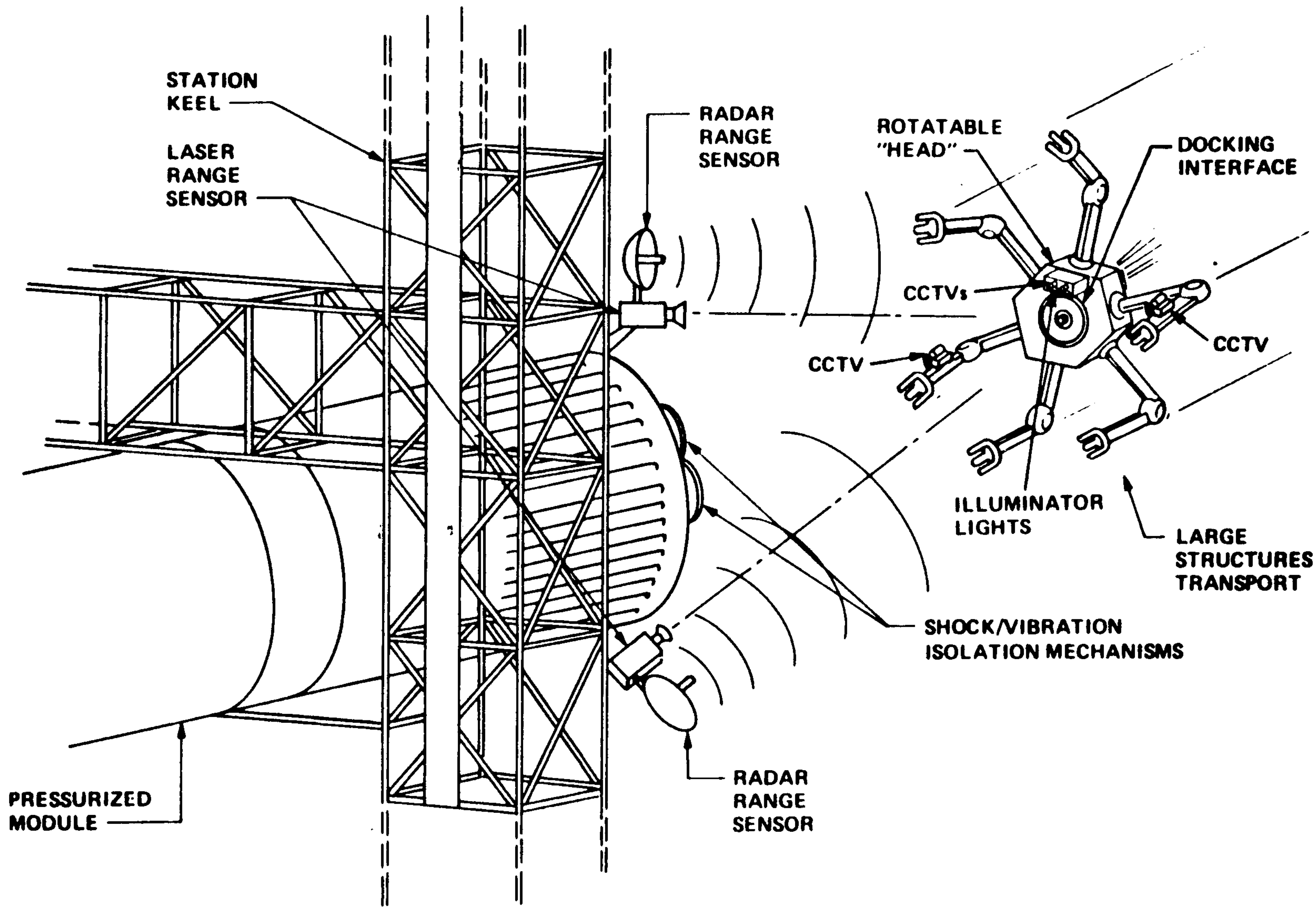
O EXPERIMENT OBJECTIVES

O TECHNOLOGY
- DEVELOP, DEMONSTRATE AND EVALUATE BERTHING/DOCKING MECHANISMS, WHICH UTILIZE PASSIVE AND ACTIVE VIBRATION ISOLATION TECHNIQUES FOR LARGE SPACE PLATFORM AND FREE FLYING AUTONOMOUS/TELEOPERATED SYSTEMS.
- DEMONSTRATE PROXIMITY AND RENDEZVOUS OPERATIONS IN SUPPORT OF SPACE STATION.

O SPACE STATION
- PROVIDE TECHNOLOGY FOR ADVANCED DOCKING/BERTHING SYSTEMS FOR SHUTTLE, SPACE PLATFORMS AND FREE FLYER.
- CHARACTERIZE FACILITIES SUPPORT FOR DOCKING, BERTHING OF LARGE STRUCTURES (POWER/THERMAL, COMMUNICATION, DATA PROCESSING, FLEXIBLE PAYLOAD ACOMMODATIONS/STORAGE, MANPOWER).

- O EXPERIMENT 1: RANGE SENSING AND BERTHING
  - O DEMONSTRATE THE USE OF ADVANCED RANGE SENSORS FOR AIDING PROXIMITY AND RENDEZVOUS OPERATIONS.
    - (1) USE OF RADAR FOR LONG DISTANCE (0 - 15 MILES) COOPERATIVE AND NON-COOPERATIVE SENSING (E.G. ALLIED BENDIX MILLIMETER WAVE RANGE/RANGE RATE SENSOR).
    - (2) USE OF LASER FOR CLOSE-UP (0-0.6 MILES) COOPERATIVE AND NON-COOPERATIVE SENSING (E.G. JPL SHAPES)
  - O RANGE SENSOR WILL GENERATE DATA FOR ESTIMATING THE ATTITUDE, VELOCITY AND THE DISTANCE OF A MOVING VEHICLE, USING TRIANGULARIZATION AND OTHER TECHNIQUES.
  - O TEST THE ACCOMPANYING USE OF ADVANCED PASSIVE AND ACTIVE VIBRATION ISOLATORS IN BERTHING AND DOCKING PROCESS OF A LARGE FREE-FLYER.
  - O LARGE STRUCTURES TRANSPORT WILL APPROACH THE SPACE STATION AND:
    - (1) MAINTAIN REAL-TIME DYNAMIC STATIONKEEPING WITH THE STATION AS A MEANS OF ASSESSING AND EVALUATING BERTHING TECHNIQUES.
    - (2) DOCK WITH THE STATION TO EVALUATE AND APPRAISE THE VIBRATION ISOLATION/DISTURBANCE REJECTION QUALITIES OF THE DOCKING MECHANISMS.
- O EXPERIMENT 2: DOCKING AND IMPACT-TESTING
  - O DEMONSTRATE THE UTILITY AND OVERALL EFFECTIVENESS OF DISTURBANCE REJECTION AND SHOCK INSULATION QUALITIES OF ADVANCED VIBRATION ISOLATORS.
  - O TEST AND EVALUATE THE MECHANICAL CHARACTERISTICS OF THE VIBRATION ISOLATORS THROUGH A SERIES OF CONTROLLED IMPACTS TO SIMULATE COLLISION IN THE PROCESS OF HARD DOCKING USING A SPACE TRUSS DELIVERED BY THE LARGE STRUCTURES TRANSPORT.
  - O PASSIVE AND ACTIVE VIBRATION ISOLATION TECHNIQUES WILL BE EVALUATED IN TERMS OF OVERALL EFFECTIVENESS AND TIME RESPONSE CHARACTERISTICS.

JPL TDMX: BERTHING/DOCKING MECHANISMS AND CONTROL EXPERIMENTATION OVERVIEW—ILLUSTRATED



ACCOMMODATION REQUIREMENTS

EXPERIMENT TITLE: TDMX - BERTHING AND DOCKING MECHANISMS AND CONTROLS

PRINCIPAL INVSTIGATOR(S): RAYMOND WOO/DR. NEVILLE MARZWELL

ADDRESS: BUILDING 198 ROOM 326

PROPOSED FLIGHT DATE 1995 YEAR(S)

OPERATIONAL DAYS REQUIRED 60 (PER YEAR)

MASS 1400. KG

VOLUME: 26.0 M^3

STORED W 4. x L 3. x H 2. = 24.0 M3

DEPLOYED W 3. x L 2.5 x H 4. = 30.0 M3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED NO (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) ______

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	8	Hrs/Day	1	No. of days.		
OPERATIONS:		Hrs/Day		No. of days.		Interval
SERVICING:	4	Hrs/Day	2	No. of days.	30	Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	2	Hrs/Day	1	No. of days.		
OPERATIONS:	9	Hrs/Day	15	No. of days.	30	Interval
SERVICING:	5	Hrs/Day	1	No. of days.	30	Interval

POWER REQUIRED:

3.50 AC/1.40 DC KW AC & DC ~~AC or DC~~ (circle one)

9 Hrs/Day 60 No. of days

DATA RATE: .01 Megabits/second

DATA STORAGE: .650 Gigabits

SPACE SPIDER CRANE

Presentor: Ian O. MacConochie
Space Systems Division
Langley Research Center

For Presentation

at

The In-Space Research, Technology
and Engineering (RT&E) Workshop

National Conference Center
Williamsburg, Virginia

Contributors:
Langley Research Center
Jack E. Pennington, FDCD
Charles F. Bryan, Jr., FD
Andrew D. Carey, RIAD
Bobby E. Silverthorn, RIAD
Hew-Esco
Rebecca L. Kinkead

Experiment Objective: To study the kinematics and dynamics of a quadruped (robotic) crane in a zero gravity environment walking on a sample space structure.

Experiment Description: The Space Spider Crane would be deployed on a structure which has been previously deployed (but still attached to) the Shuttle cargo bay. The test sequence is as follows:

1) The Spider Crane would be unfolded from the stored position.

2) Each joint and end effector would be functionally tested for ability to move and each member tested for ability to maneuver and grapple structure. Positioning accuracy and grappling forces would be monitored.

3) The crane would displace itself from the storage area in the cargo bay to the example space structure. This motion would be accomplished using only two legs of the crane; one leg to grapple the fixture in which it was stored. Movement of this leg would be used to position the body of the crane so that a second leg could grapple the sample deployed structure.

4) Conduct a two legged walking test.

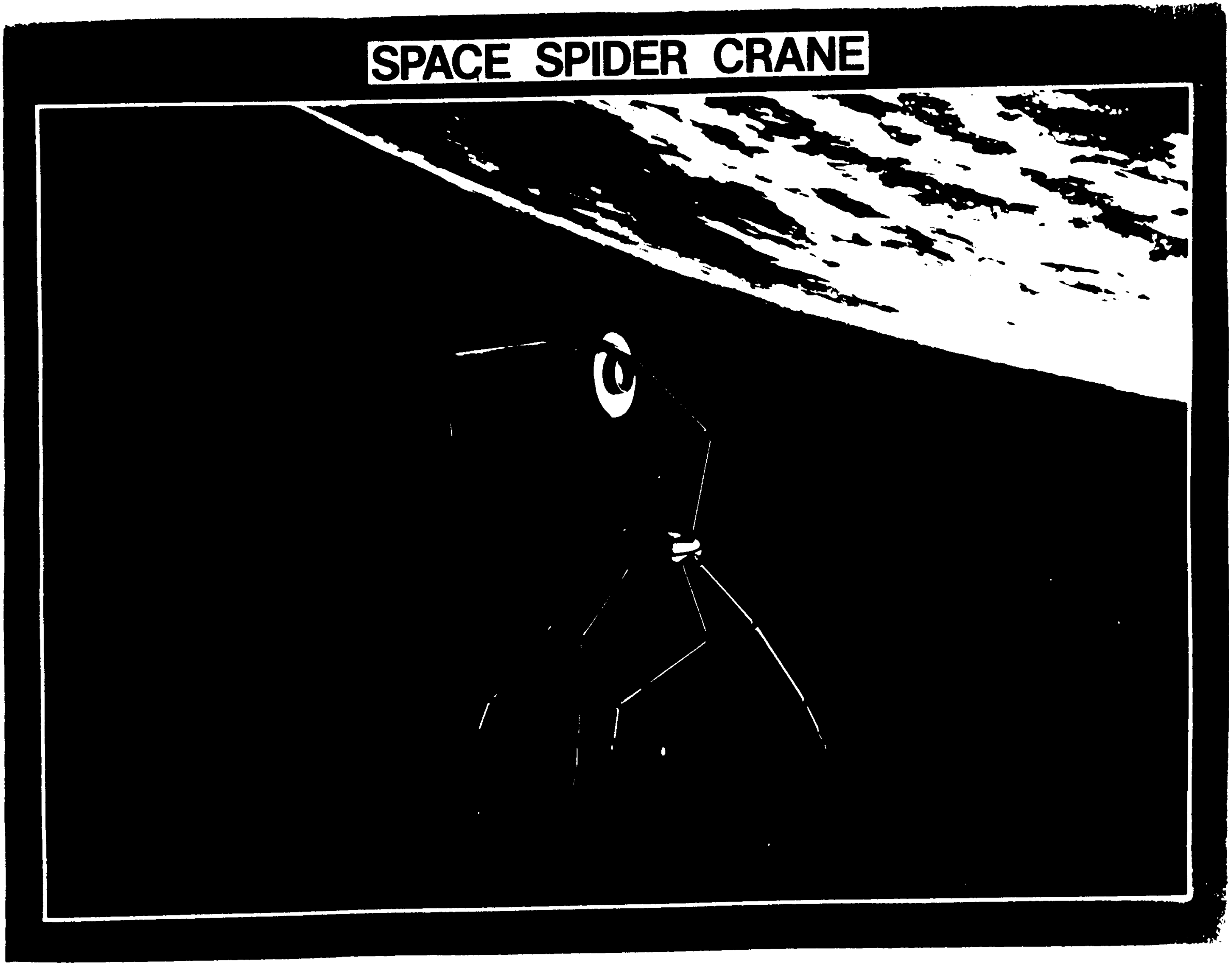
5) Conduct a four legged walking test.

6) Perform a grappling test of a sample payload using the two Spider Crane arms. The turret drive of the Spider Crane would be tested.

7) Perform a walk along the sample structure with payload.

8) Re-stow the Spider Crane, sample payload, and sample structure for Shuttle return.

NASA
L-85-422



EXPERIMENT TITLE: Space Spider Crane

PROPOSED FLIGHT DATE - 2010 **YEAR**

OPERATIONAL DAYS REQUIRED - 4

MASS - 150 **KG**

VOLUME:

STORED **W** 0.6 **x L** 2.4 **x H** 0.6 **=** 0.9 M^3

DEPLOYED **W** [illegible] **x L** [illegible] **x H** [illegible] **=** [illegible] M^3

INTERNALLY ATTACHED ______ **(YES/NO)**
EXTERNALLY ATTACHED X **(YES/NO)**
FORMATION FLYING ______ **(YES/NO)**

ORIENTATION (inertial, solar, earth, other) Referenced to Structure to which attached.

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	0	**Hrs/Day**	0	**No. of days**		
OPERATIONS:	0	**Hrs/Day**	0	**No. of days**	____	**Interval**
SERVICING	2	**Hrs/Day**	2	**No. of days**	1	**Interval**

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	4	**Hrs/Day**	2	**No. of days**		
OPERATIONS:	4	**Hrs/Day**	2	**No. of days**	1	**Interval**
SERVICING	0	**Hrs/Day**	0	**No. of days**	0	**Interval**

POWER REQUIRED:

0* **KW** **AC or DC (circle one)**

\- **Hrs/Day** - **No. of days**

DATA RATE: 6 **Megabits/second**

DATA STORAGE: 3 **Gigabits**

* Internal power